9. *The* TARNS *of the* CANTON TICINO (SWITZERLAND). By EDMUND J. GARWOOD, M.A., Sec.G.S., Professor of Geology in University College, London. (Read June 7th, 1905.)

[PLATES VII—XXI.]

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I. INTRODUCTION.

THE study of lakes, so long neglected by geographers in the past, has of recent years received a great impetus from the investigations of Prof. Forel,[1] M. Delebecque,[2] Prof. Penck,[3] and other workers on the Continent, and of Prof. Russell,[4] Prof. Gilbert,[5] and Prof. W. M. Davis [6] in America; while in our own country, Dr. Mill,[7] Dr. Marr, Sir John Murray,[8] Mr. Pullar, and others have aroused our interest in this fascinating subject.

In his exhaustive 'Handbook of Limnology,' Prof. Forel remarks:—

> 'Each lake is an organism in itself, each has its peculiarities, its special history in the past and in the present, each deserves a special description. Hence the charm and also the scientific value which attach to the study of lakes in general and to that of each lake in particular.' [9]

Of all the numerous interesting branches of study connected with lakes, that of the origin of the hollow in which the lake occurs is the one that must especially appeal to the geologist; while of these hollows, those basins that are entirely surrounded by solid rock are certainly the most interesting and the most difficult to explain.

The theory, originally advanced by the late Sir Andrew Ramsay, and supported by Tyndall, Gastaldi, and de Mortillet, which would have us regard the majority of the large Alpine lakes as due to the direct erosive action of ice, has gradually given rise to a detailed consideration of the genesis of each individual lake.

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[1] F. A. Forel, 'Le Léman' Lausanne vols. i–iii (1892–1901).

[2] A. Delebecque, 'Les Lacs Français' Paris, 1898.

[3] A. Penck, 'Morphologie der Erdoberfläche' pt. ii (1894) pp. 203–327.

[4] I. C. Russell, 'Geological History of Lake Lahontan' U.S. Geol. Surv. Monogr. xi (1885).

[5] G. K. Gilbert, 'Lake Bonneville' U.S. Geol. Surv. Monogr. i (1890).

[6] W. M. Davis, 'On the Classification of Lake-Basins' Proc. Boston Soc. Nat. Hist. vol. xxi (1882–83) p. 315.

[7] H. R. Mill, 'Bathymetrical Survey of the English Lakes' Geogr. Journ. vol. vi (1895) pp. 46, 135.

[8] Sir J. Murray, 'Bathymetrical Survey of the Freshwater Lochs of Scotland' Geogr. Journ. vols. xxii–xxvii (1903–1906).

[9] 'Handbuch der Seenkunde' Stuttgart, 1901, p. 9.

At the present day, several eminent authorities still attribute the origin of some of the larger Swiss and Italian lakes to ice-erosion. Thus Prof. Brückner, in his recent work,[1] considers that the Lake of Zürich was created by glacial overdeepening, and that it represents the end of an old valley which was overdeepened by the Linth Glacier; he also attributes the formation of the Lakes of Zug and Lucerne to the same agency.[2] Prof. Davis again, in his paper on 'Glacial Erosion in the Valley of the Ticino,'[3] attributes the rock-basin of the Lago Maggiore to direct ice-erosion. It is evident, therefore, that this theory is in no wise extinct. On the other hand, many Swiss and Austrian geologists, notably Prof. Heim and Dr. Forel,[4] attribute all these lakes to post-Miocene earth-movements in one form or another. These lakes, which are of considerable size, all occur in the outer zone of the Alps, or the 'Kalk-Alpen' of Continental writers, and are often spoken of as 'Randseen' or marginal lakes. It is not, however, with these that I am at present concerned.

The lakes, the origin of which I intend to discuss in the present communication, are those to which in this country the name 'tarn' is frequently applied; they occur invariably in mountain-districts, and in the Alps are confined to the 'Hochgebirge.' They may be defined as lakes draining into the principal Alpine valleys, whereas the Randseen receive the drainage of these valleys.

These tarns, although they frequently occur as 'corrie'-lakes, include also others which, strictly speaking, do not come under this category. Of these latter, some are true rock-basins; while others owe their origin to the damming of valley-drainage by loose material.

Not long ago, Dr. Marr, in writing of the 'Tarns of Lakeland,' pointed out that many, if not all, of them were due to accumulation, and expressed a doubt as to whether any lakes of this class would eventually prove to be true rock-basins. Whatever may be the case in Cumberland, there can be no doubt of the occurrence of true rock-bound tarns among the 'Hochgebirgseen' of the Alps.

In the pages of the 'Geological Magazine' for 1898,[5] Prof. Bonney instanced a group of lakes in the neighbourhood of Airolo, which he unhesitatingly described as true rock-basins, and referred provisionally to excavation by ice; though, in the case of Lake Ritom, at all events, he 'saw difficulties.' A glance at the geological map of Switzerland shows that these lakes lie along the outcrop of certain Mesozoic limestones. It is also noticeable that, if traced westwards from the Airolo district, other lakes, such as the Engstlensee and the Trubsee, are found to be situated on the outcrop of the same rocks. Furthermore, it is obvious that many of the chief valleys and passes, such as the Val Bedretto and the Nufenen Pass, or again the Urserenthal and the Furka Pass, have been excavated along the strike of these calcareous rocks.

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[1] A. Penck & E. Brückner, 'Die Alpen im Eiszeitalter' Leipzig, Lieferung 5 (1903) p. 525.

[2] *Op. cit.* pp. 537–88.

[3] 'Appalachia' vol. ix (1900) pp 151–52.

[4] A. Heim, 'Die Entstehung der Alpinen Randseen' Vierteljahrsschrift der Naturforsch. Gesellsch. in Zürich, vol. xxxix (1894) p. 66; and F. A. Forel, Bull. Soc. Vaud. Sci. Nat. ser. 3, vol. xxvi (1890–91) Proc.-verb. pp. xii, xvi & 'Le Léman' vol. i (1892) pp. 211 *et seqq.*

[5] P. 15 [not p. 45, as stated in the index of that volume].

In noting these facts, I felt convinced that the occurrence of so many tarns along the outcrop of the same beds as those in which the valleys and passes had been excavated, must point to something more than mere chance coincidence. An especial interest attaches to these lakes, inasmuch as they include the group the origin of which Prof. Bonney has hesitatingly conceded to ice-erosion. I have, therefore, devoted portions of my summer-holidays during the past few years to their investigation.

I began work on the western group of lakes, which lie to the west and north of the Titlis. A preliminary survey showed that no definite conclusions could be reached, without some knowledge of the depth and general form of the lakes; none of these lakes, however, had been sounded, and this work yet remained to be done. One great obstacle presented itself to the immediate accomplishment of this preliminary step, in the fact that the majority of the tarns are destitute of boats. After consideration, I abandoned the idea of a portable boat, as the lakes are seldom free from wind after sunrise, and the accuracy of the soundings obtained from a drifting coracle seemed to me to leave a good deal to be desired.

Eventually, with the assistance of a grant from the Government-Grant Committee of the Royal Society, I succeeded in constructing a sounding-machine which could be used from the banks without a boat, capable of yielding very accurate results, being self-registering both as to the depth and the positions of the soundings. With this instrument I made a detailed survey of the group of lakes of the Val-Piora district, and later included other important tarns of the Canton Ticino. In the work of sounding these tarns I received great assistance from my friends, Miss Violet Wainewright, Mr. Haworth Moberly, and Dr. Ernest Kingscote, to each and all of whom I tender my sincere thanks, not only for the results that they accomplished, but for the way in which, by their ever-ready help and interest, they converted a somewhat tedious piece of work into a summer-recreation.

In the following pages I have endeavoured to bring together such facts as seem to bear on the origin of these lakes; but I have not yet had the opportunity of visiting all the tarns in the Canton Ticino, and my remarks must therefore be taken to apply only to those lakes which are actually described.

II. THE LAKES OF THE VAL PIORA.

[Pl. VII—topographical map, facing this page.]

These lakes lie in a series of hollows in and around the mountain-glen of the Val Piora. This depression has been carved out of a series of limestones and schists, which have been squeezed in between two masses of gneiss—one of these forming the northern wall of the Val Levantina below Airolo, and the other constituting the Val-Cadlimo district on the north. That the majority of these lakes occupy rock-basins is clearly shown in Prof. Bonney's careful description.[1] I will reserve any further general remarks until I have described the lakes in detail, when we shall be in a better position to discuss the evolution of the district as a whole.

Lago Ritom (see Pls. VII, VIII, & XVI) is situated exactly 6000 feet above sea-level, and occupies a true rock-basin. It has a length of about 2190 yards, and a width (at the upper end) of some 590 yards, becoming narrower towards the exit. It is fed chiefly by three streams, namely, the Murinascio torrent, draining the Val Piora, and the two streams carrying the overflow from Lago Tom and Lago Cadagno respectively. These last-named lakes receive the drainage from two unnamed tarns, to which, for convenience, I shall refer as Lago Taneda and Lago di Murinascio. The former (namely, Lago Taneda), which lies on the watershed, drains southwards through the Lago Cadagno. Lago di Murinascio has no true exit; any surplus-water that there may be finds its way through the screes which form the lowest point of its containing barrier. Lago Ritom must once have extended nearly 1000 yards farther to the north-east, over the area now occupied by a delta which forms a swampy alluvial flat; a delta which, from its peculiar situation, might well be used to ascertain the length of time that has elapsed since the close of the Glacial Period in this district. The southern shore of the lake is formed of coarse foliated gneiss, dipping north-north-westward at about 35°; while the northern bank runs along the foot of a steep escarpment of calcareous crystalline schists—a complicated series, much folded, contorted, and crushed. At the south-eastern corner of the delta, outcrops of rauchwacke and dolomite occur; and the same beds must form the floor of the lake throughout its length, for they reappear at its western end, where they are found cropping out close to the Hotel, while beds of a similar calcareous character occupy most of that end of the lake in places up to the 1980-metre contour. As this fact is not at all clear from Dr. K. von Fritsch's map, where only a small patch of rauchwacke is shown, forming the saddle between Pian' Alto and Fongia, a brief description of the rocks that occupy this end of the lake is necessary.

Starting from the exit of the lake, we find the water of the Foos running out over the southern mass of gneiss. This rock can be

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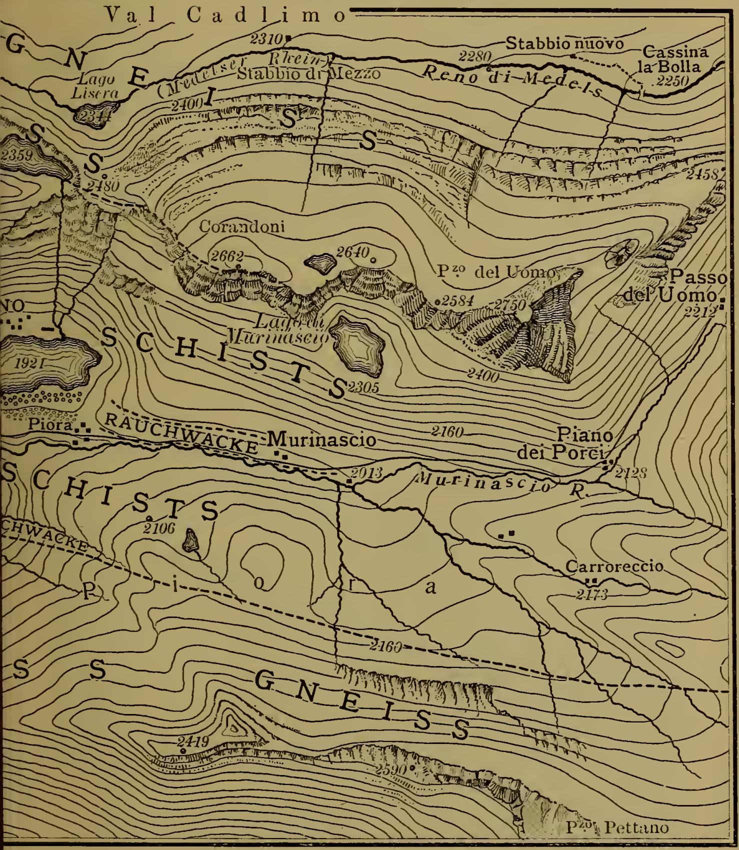
[1] Geol. Mag. 1898, pp. 15 *et seqq.*

Quart. Journ. Geol. Soc. Vol. LXII, Pl. VII.

:42240.
xpressed in metres.

The Val Ticino lies just outside the map, below it; & the Val Canaria lies also just outside the map, sensibly parallel with its Western margin.

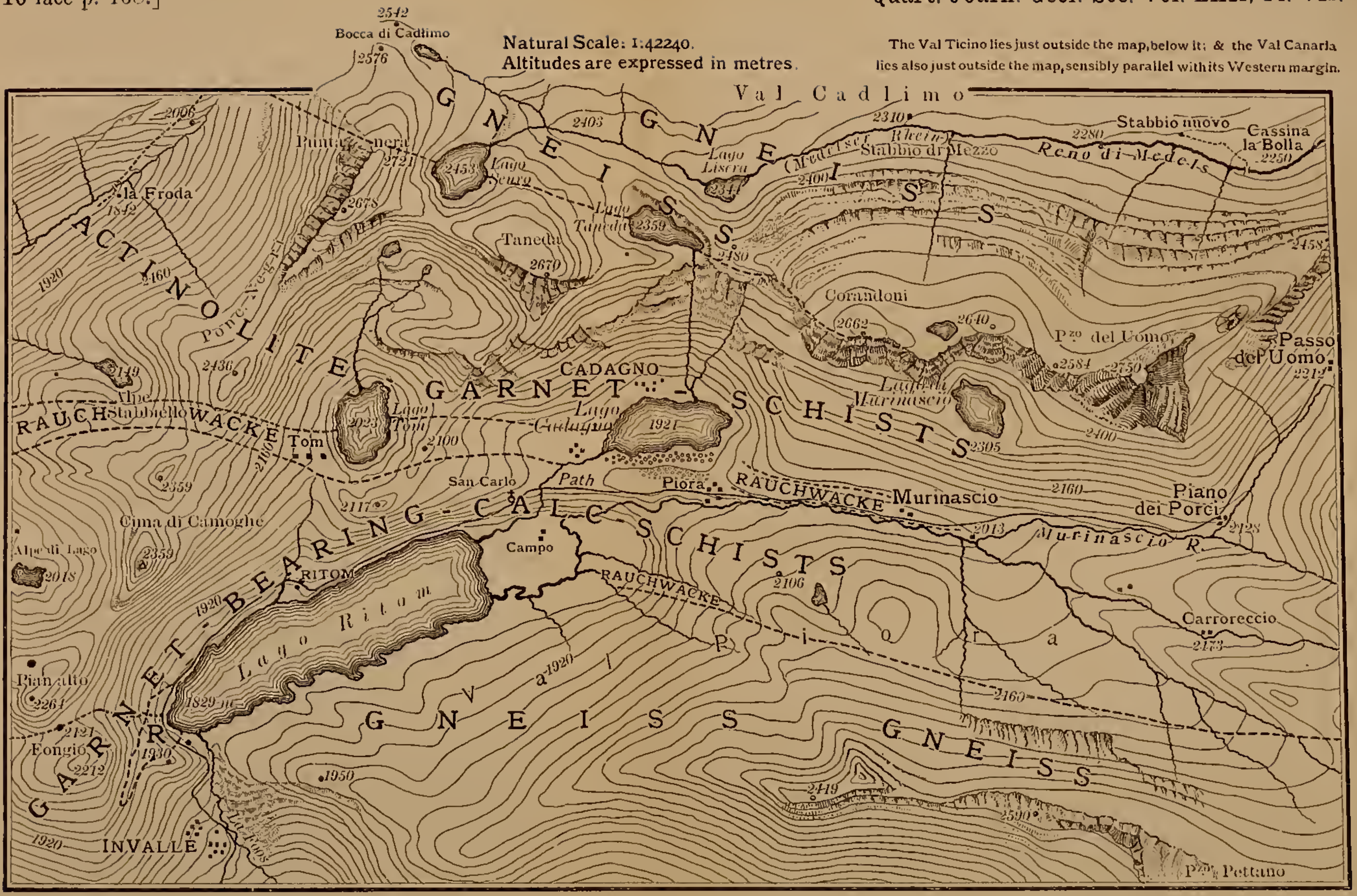


HE PIORA LAKES.

e extreme left-hand corner of the map, between Pian alto and Fongio. Also
bove the numerals of altitude 2013, north of the Murinascio stream.]

To face p. 168.]

Quart. Journ. Geol. Soc. Vol. LXII, Pl. VII.


Natural Scale: 1:42240.
Altitudes are expressed in metres.

The Val Ticino lies just outside the map, below it; & the Val Canaria lies also just outside the map, sensibly parallel with its Western margin.

MAP OF THE PIORA LAKES.

[A triangular patch of rauchwacke should have been indicated in the extreme left-hand corner of the map, between Pian alto and Fongio. Also the occurrence of gypsum should have been indicated just above the numerals of altitude 2013, north of the Murinascio stream.]

followed for a few yards past the Hotel to a point where the path to Pian' Alto turns up to the left. Here the gneiss dips under the end of the lake, and is not again seen; north of this no outcrop of rock in place is met with, until we reach a conspicuous gully which ends in a well-marked delta, the broad depression that intervenes being obscured by fallen talus. If, however, we turn up the path to Pian' Alto, we find that the gneiss is immediately overlain by a bed of pale pink rauchwacke, closely resembling in texture the rock which crops out at the south-eastern end of the lake.

The junction between the gneiss and the rauchwacke runs almost along the track leading to the little knoll behind the Hotel, marked 1930 m. in the Swiss Government map (see Pl. VII); in fact, the track has taken this line up the dip-slope of the gneiss, on account of the depression formed by the unequal weathering at the junction of these two rocks. From here the outcrop of the calcareous rock can be traced northwards, across the scree-covered depression, to a conspicuous bluff occupied by a small plantation of nine fir-trees. Here the rock is rather lighter in colour and much honeycombed, and closely resembles the rock surrounding the exit-end of Lake Tom. Masses of this rock are found in the gully-section farther north; and it crops out again farther on, by the side of the path running round the north-western edge of the lake (see Pl. XIII, fig. 1).

If we now follow the upper portion of the outcrop, south from the tree-covered bluff, we find a conspicuous band of the same rock, 40 to 50 feet thick, running for some distance round the eastern flank of Fongio, behind the 1930-metre hill, and dipping at some 6° to 10° northwards in the neighbourhood of the 1980-metre contour-line. After continuing for some distance in this direction, it ceases abruptly. It is found, however, a few yards below, on the path running round the hill into the Val Canaria. An analysis of this band is given below (p. 177).

The rock is everywhere micaceous, and in places contains large tufts of actinolite, which appear to be arranged roughly along certain planes. A good section, showing nests of actinolite-crystals, is exposed in the little quarry at the back of the Hotel.

It will be seen, then, that from the edge of the gneiss the western end of Lake Ritom is composed of calcareous rocks, up to a height of 1980 metres. The abrupt disappearance of this mass at either end of the outcrop is very suggestive; and we may, I think, regard the area occupied by Lake Ritom as a large lenticle of calcareous rock, possibly including a bed of gypsum, enclosed between the gneiss on the south and the crystalline schists on the north.

An interesting feature is brought out by a comparison of the northern and southern shore-lines of the lake. The former, disregarding the scree and delta-material, is seen to run in a straight line along the length of the lake; the latter, on the other hand, is broken by numerous bays and rocky headlands (see Pl. VIII).

The surface of the southern mass of gneiss, as shown above, can be traced westwards under the calcareous rocks on the north side of the 1930-metre hill. It represents therefore almost exactly the former line of junction of this gneiss with the overlying rauchwacke, now removed by denudation over the area occupied by Lake Ritom; and the existence of the bays and headlands seems in some cases to have been determined by folds or crumplings, which must once have affected both sets of rocks, as will appear by an inspection of the bathymetrical contours. Some of the bays, however, are due to stream-erosion, as shown by the abruptly-truncated strike.

The general shape of this lake-basin is indicated on the bathymetrical chart (Pl. XVI). The greatest depth met with was 163 feet, in the centre of the lake. The greater part of the lake is over 100 feet deep; while an area, about 330 yards in length and 150 feet or more in depth, occupies what must originally have been the centre of the lake, if we allow for the portion at the upper end which is now filled with delta-material. The floor of Lago Ritom is thus seen to form a very symmetrical trough, the axis of greatest depth running east and west, practically down the middle of the lake. The contours near the southern side are influenced by the subaqueous folds of the gneiss for some distance from the shore. The contours along the northern bank bear no particular relation to the subaërial escarpment, being chiefly influenced by landslips and rock-falls from the steep cliffs above: were it not for the loose material thus accumulated, the northern shore would undoubtedly descend much more steeply than it now does.

Lago Tom (see Pls. IX, X, XII, & XVII).—This lake lies at an elevation of 6637 feet above the sea. It occupies a hollow directly above, and to the north of, Lago Ritom. In shape it is a rough oval. Its greatest length from north to south is exactly 550 yards, and its greatest width from east to west about 350 yards.

Prof. Bonney remarks in a footnote (*op. cit.* p. 19):

> 'Its area is given as 1000 square metres, and it is said to be shallow. But I should think it would not be less than some 20 feet deep, and might be more.'

The greatest depth that I obtained was exactly 50 feet. The lake, again to quote Prof. Bonney:

> 'occupies a kind of cirque, and lies in the strike of the same rocks [as Lago Cadagno], for the enclosing crags consist of similar amphibolitic and granatiferous gneiss, and at the lower end is rauchwacke, which can be traced from the southern side of the basin of the Lago Cadagno across the intermediate spur.'

The lake terminates at its southern end in a wall of rauchwacke, about 16 feet high. A short gorge leads into the heart of the rauchwacke, near the eastern end of this wall; and after heavy rain, when the lake is high, I have seen the water flowing through this channel and disappearing underground. It reappears as a spring farther west, on the south side of the barrier of rauchwacke, exactly at the junction of that rock with the underlying schist. After a spell of fine weather the level of the lake falls so that the water does not reach the channel, and a broad, flat beach is laid bare at the south-western end of the lake; the spring, however, continues to issue at the same spot. This 'terminal' wall of rauchwacke is rotten and honeycombed, and just above the spot where the spring now issues is situated a large cave which evidently represents the old source of the spring, when it escaped higher in the rauchwacke (see Pl. XII, fig. 1). Apparently it has gradually dissolved its way down to the level of the insoluble schist, against which it is now thrown out. The rock is a fine-grained metamorphosed limestone containing some 16 per cent. of dolomite, and 8 per cent. of insoluble material, chiefly silica.

The bathymetrical chart (Pl. XVII) shows the general shape of the lake-floor. The maximum depth of 50 feet is situated about one-third of the way from the northern end of the lake. The axis of greatest depth runs east and west, and passes through this point. It is parallel to the strike of the rocks, and appears to coincide with the junction of the rauchwacke and the overlying crystalline schist. The shore of the lake is entirely formed of delta-material and sand, with the exception of the southern wall of rauchwacke described above. But for this the upper end of the lake would, as in the case of Lago Ritom, undoubtedly show deeper soundings near the northern shore. The flat shallow bay occupying the southern end between the delta and the exit-channel has an average depth of about 3 feet, and is strewn with fragments of minerals, many of them presumably derived from crystalline schists. These coarser fragments must have been brought down by the stream descending between the rauchwacke and the overlying schists; and it is a very suggestive fact that, although fragments of mica clearly derived from the rauchwacke are represented, no pebbles of this rock are found, despite its occurrence here *in situ* round the end of the lake.

Lago Cadagno (see Pls. XI & XVIII) lies due east of Lago Tom, at the somewhat lower level of 6302 feet. It is situated apparently on the strike of the same beds (namely, the rauchwacke on the south, and the overlying crystalline schists on the north), and occupies a slight synclinal depression. It is surrounded by alluvium and scree-débris, with the exception of the north-eastern corner, where solid rock occurs, and the southern bank, where the rock is plastered with morainic material. The lake doubtless once extended to the rocky barrier over which the river now falls into Lago Ritom; but the western end has been filled up by material washed down from the steep escarpment on the north and north-west. It is possible that it once drained from its south-eastern end. The lake is 875 yards long and about 330 yards in width, the greatest depth being 62 feet. The bathymetrical chart (Pl. XVIII) shows that it is a symmetrical spoon-shaped hollow, having an axis of greatest depth running east and west, parallel to the length of the lake, situated nearer to the northern than to the southern shore. It is fed by a group of some ten or twelve streams which cascade down the precipitous scarp-face on the north. Most of these originate in patches of snow, which lie throughout the greater part of the year in hollows near the watershed; but one, the lowest, occupying the centre of the cirque, originates in the little Lago Taneda mentioned on p. 168. This cirque is a good example of an escarpment-cirque, formed by a series of streams which derive a constant supply from lakes and melting snow. The water from Cadagno winds through the alluvial and morainic material mentioned on the previous page, to the edge of the rock-escarpment of quartz-calc-garnet schist; but the fall is very slight, probably not more than a few feet. The rock-basin of Cadagno must, therefore, be at least 50 feet deep. From the edge of the escarpment the water plunges abruptly into the Ritom basin, down a cliff 100 feet high, near the centre of the synclinal fold.

Lago Scuro (see Pls. XII & XIX) is undoubtedly one of the most interesting of the lakes in this district. It lies at a height of 8048 feet, and is situated almost on the watershed between the Ticino and the Reno di Medels (or Medelser Rhein), its exact position being some 150 or 160 feet below the summit of the ridge on the northern side. It drains through the Val Cadlimo into the Medelser Rhein, and occupies a true rock-basin, which lies along the junction between the schist and the northern mass of gneiss.

It is roughly oval in shape, and has a longer diameter of 404 yards, which runs north-north-east and south-south-west. The only drainage that it receives is derived from the melting snow round its sides, and it discharges its surplus water down a rocky channel into the Cadlimo River. The bathymetrical chart (Pl. XIX) shows it to have a maximum depth of 138 feet. The contours run roughly parallel to the shore, and the axis of greatest depth lies east-north-east and west-south-west, in the general direction of the junction of the gneiss and the crystalline schists. The shore is entirely formed by rock *in situ* with occasional loose blocks, while a patch of snow permanently occupies a portion of the eastern bank. The dip of this schist is about 40° northward, but it can be seen sweeping round in a basin-like curve across the southern end of the lake. Soundings show that ridges of rock continue under water for some distance out, and thin bands of harder material have weathered out so sharply as to cause considerable trouble in using the sounding-line.

Lago Taneda (for contour-map, see Pl. XX) occupies a rock-basin, lying at a height of 7740 feet, and is situated along the same line of strike as Lago Scuro. According to Dr. Fritsch, who mapped the district in detail, the junction between the northern mass of gneiss and the underlying schist runs down the middle of the lake. The relation between these rock-masses at the exit is not very clear; but the gneiss is well seen, forming the watershed above the north side of the lake, where it appears to be iceworn. The southern shore is formed of a gneissose mica-schist dipping about 40° northward; but immediately below this, on the track leading down to Lago Cadagno, an outcrop of black hornblende-schist occurs. The rocks forming the shores of the lake are jagged and broken, and show no signs of ice-abrasion. The cliff of gneiss above the northern and eastern shores is interrupted and broken down towards the north-west, where a low col leads over into the Val Cadlimo. The lowest point of this col lies some 150 feet above the present level of the lake. Another, but less well-marked depression, leads from the spring on the north-western shore to a small pool, which drains into the Lago Lisera in the Val Cadlimo.

Lago Taneda is, therefore, situated as nearly along the watershed as may be, and it is probable that it drained at some former time over one or both of these gaps into the Val Cadlimo; possibly during a temporary obstruction at the present outlet, or before it had been cut down to its present depth.

The greatest length of the lake from east-south-east to west-north-west, along the line of strike, is 490 yards; and the greatest depth is 140 feet, practically the same as that of Lago Scuro. The bathymetrical chart (Pl. XX) shows that the greatest depression is situated towards the western end of the lake, while the narrower south-eastern end forms a shallow bay. There is, however, a general axis of greatest depth running along the length of the lake parallel to the strike of the rocks, which probably coincides with the junction between the gneiss and the schistose rocks.

Lago di Murinascio, alone among the tarns in this district, is situated wholly in one set of beds. It lies at a height of 7562 feet, and occupies a corrie in the northern wall of the Val Piora, above the Murinascio Alp. It belongs to the upper group of lakes represented by Lago Taneda and Lago Scuro. The lake is not entirely rock-bound, the water at the lower end being held up by scree-material. No soundings were made, as this lake is not a true rock-basin, and there is no exit. A ridge of rock, however, forms the shore on the south side, and it may possibly be a shallow rock-basin.

Lago Lucomagno, situated in a corrie on the south-western flank of the peak of that name, is partly scree-dammed, but must be a rock-basin some 40 feet deep. It drains directly into the Ticino below Varengo, but in this case, as in that of Lago Tom, there is no overflow. A spring (which issues some 500 feet below) appears, however, to derive its supply from this lake. The lake is almost divided into two separate sheets of water by a narrow peninsula. The water at the lower end is partly held up by rock-falls and screes, and partly by rock *in situ*, and is situated along a strike-ledge in the gneiss. The depression which the lake occupies can be seen continuing as a line of weakness to the east, where it is weathered out into a gully in the hillside.

A little tarn, not shown on the Government map, occurs on the northern slope of the same mountain, but it is obviously due to a landslip, and does not require our further attention.

Lago Camoghè, lying on the western slope of the peak of that name, is another example of a scree-dammed tarn. Its formation may, however, have been influenced by the occurrence of a bed of rauchwacke, which occupies the pass between Pian' Alto and the Cima di Camoghè. This rock, although not so shown in Dr. K. von Fritsch's map, appears to strike round the south-western end of this lake, and reappears at the head of the gully at a point where the spring issues a little below the Alpe di Lago.

The Origin of the Piora Lakes.

So far as I am aware, only one writer on this district has expressed any opinion regarding the origin of these lakes, namely Prof. Bonney, in his paper in the 'Geological Magazine' for 1898, already quoted.[1] In discussing the possibility of their formation by ice-erosion, he does so, evidently, with a desire to give all due weight to a theory which is perhaps that most generally held in regard to the formation of lakes of this class; but he is obviously not quite satisfied, himself, with the application of the theory to these particular lakes. I will, in the first place, point out the serious difficulties in the way of accepting this theory, and afterwards suggest what seems to me a more probable mode of origin.

Let us first take Lago Ritom. In the case of this lake, there are only three directions in which ice can reasonably be assumed to have travelled, namely: (1) from the depression between Pian' Alto and Fongio at the western end of the lake; (2) from the district on the north, now drained by Lago Tom; (3) from the Val Piora on the east, including possibly a tributary from the cirque now occupied by Lago Cadagno (see Pls. VII & XI).

In the first case, there would be no sufficient gathering-ground inside the Ritom drainage-area, and ice advancing from this quarter must have originated outside the district and overtopped the western watershed; but we have no evidence of an accumulation of ice in the district to this depth, and had the ice in the Val Ticino reached to this height, it would have invaded the Ritom basin much more readily from the east through the present exit of the lake, which is nearly 1000 feet lower.

The second case postulates a glacier descending from Lago Tom. This could not possibly have excavated the upper end of Lago Ritom, and consequently this supposition may be at once dismissed.

There remains only the third alternative, namely that of a glacier descending the Val Piora, augmented possibly by ice from the Lago-Cadagno basin. There can be no doubt, I think, that this district lay above the snow-line during the Pleistocene Period, and that snow and ice accumulated here and occupied the Val Piora. My difficulty lies in understanding how this ice could acquire any velocity in moving westward along the basin now occupied by Lago Ritom, and why it should have turned off at right angles and discharged itself to the south-east, unless these lines of drainage had been previously determined.

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[1] But see also A. Delebecque, Comptes Rendus Acad. Sci. Paris, vol. cxxxix (1904) pp. 936 *et seqq.*

Prof. Bonney remarks (Geol. Mag. 1898, p. 20):—

> 'Supposing a glacier to be descending the Piora valley, we must assume this wall [at the north-eastern end of Lago Ritom] to be already in existence, or it could not acquire any plunging force, and even then the fall seems hardly adequate to produce the erosion of a basin like that of Lake Ritom. Possibly, however, the ice, just at this part, may have been "jammed"; for the main glacier was probably augmented by another ice-stream, which descended a shallow, but fairly well-marked valley, leading from a gneissic peak lying south-east down to the corresponding corner at the head of the Ritom basin; while the narrow "gate" by which the water is now discharged towards the Val Bedretto would block the mass of ice above it, and this would produce more than usual friction on the bed of the valley now occupied by the lake and its delta. This basin then, the part which lies below the present contour-line of 6000 feet (in round numbers), is the utmost that, in my opinion, can possibly be attributed to the erosive action of ice. Of this action all the other dominant features in the surrounding scenery exhibit nothing more than superficial traces, and they appear to be due to the usual meteoric agencies.'

It is this probability of the ice becoming 'jammed' at the western end of Lago Ritom which would, I think, prevent it from excavating to any appreciable extent. In a former paper, read before this Society by Prof. Gregory and myself,[1] we showed that where the lower layers of a glacier are embayed, their advance is practically checked, and shearing of the upper layers takes place over those below. Under these circumstances the greatest erosion, in the case that we are considering, would be on the surface of the rock-lip near the present exit of Lago Ritom, and it is precisely here where we find the most obvious indication of former glacial abrasion. Such erosion would, therefore, tend to destroy a rock-basin, not to produce one. Again, the presence of the rocky headlands, which have been described as occurring along the south side of the lake, jutting out to the north-west, should have protected the rauchwacke, originally occupying some of the present low bays, from ice coming down from the east; but not a trace of the rauchwacke is to be found there. So far, therefore, as Lago Ritom is concerned, it does not seem easy to account for the excavation of the basin which it occupies on the supposition that it was ice-eroded.

If we turn to the other lakes, Tom and Cadagno, the difficulty is increased. It is obvious that these lakes could not have been excavated by a glacier descending the Val Piora, and no glaciers could have formed on the nearly-vertical cliffs which hem them in to the north. If we postulate ice, other than local accumulations of snow, we must, as shown above, bring it from outside the basin. In this case it must have come over a watershed 8200 feet high, and there is no proof of the country having been swathed in ice to this enormous depth. But, supposing such ice to have poured down from the heights to the west, why, after digging out Lago Tom, did it ascend the slope of rauchwacke between Lago Tom and Lago Cadagno, only to dig Lago Cadagno again, out of the same material and along the strike of the same rocks?

Or, again, assuming that the ice poured over the watershed, down the precipices which hem in the lakes on the north, it could only have arrived at the bottom in fragments, and could at the most have contributed to a remanié glacier.

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[1] Quart. Journn. Geol. Soc. vol. liv (1898) pp. 203 *et seqq.*

Lastly, if the ice came from the north, how was the Lago Scuro excavated, or the Lago Taneda, which is entirely shut in by precipices on the north? It is, indeed, extremely difficult to account for the excavation of these last-named tarns by ice, even if we attribute to that agent the utmost power that has ever been claimed for it.

Let us take the Lago Scuro as a crucial case. Here is a rock-basin 136 feet deep, situated almost on a main watershed, within a few metres of its summit, and surrounded on three sides by steep cliffs. There is no gathering-ground above it for a glacier, and it is thoroughly protected from any ice invading the region from outside: yet we find a rock-basin of this considerable depth. I need hardly add that the steep reefs of rock running into the lake are quite inconsistent with ice-erosion. The case of Lago Taneda is still more difficult. No ice could possibly reach this lake from anywhere except a little névé from Taneda, and yet it is a deep rock-basin.

Geological Structure.—Putting aside, then, the theory of ice-erosion, we must seek for some other reason for the existence of these lakes.

Let us first of all consider, in rather more detail than we have yet done, the geological structure of the district.

All the rock-basins of this group, as shown above, are situated along the junction of two distinct types of rock. The three lower lakes lie along the strike of two nearly-parallel outcrops of rauchwacke and dolomite, and occur at the junction of these rocks with gneiss and crystalline schists.

A glance at Dr. K. von Fritsch's map shows, not only the lower lakes, but also the valley of Piora running along the outcrop of the rauchwacke and dolomite, while the same rocks occupy the two passes leading into the Val Canaria between Fongio, Pian' Alto, and the Cima di Camoghè. We have, therefore, in this district differential erosion depending on differences in geological structure, being greatest along the rocks rich in calcite and dolomite. In addition to this, the soundings show that the axes of greatest depth of all the lakes lie along the junction of calcareous and crystalline rocks.

The causes which produced the peculiar geological structure of the district still remain to be considered. In his well-known paper, 'On the Crystalline Schists & their Relation to the Mesozoic Rocks in the Lepontine Alps',[1] Prof. Bonney has argued against the inclusion of the rauchwacke and dolomite in the same metamorphic series as the crystalline schists occurring above and between them. He regards them as an entirely-separate group of rocks, introduced among the crystalline series by faults or thrusts, and rejects the idea suggested in the sections accompanying Dr. K. von Fritsch's map, that their present relation to the schists is the result of simple folds, which affected a stratigraphically-continuous series of beds.

After my first visit to the district, and before I had seen Prof. Bonney's paper, I had arrived at precisely the same conclusion; a conclusion which has been fully corroborated by subsequent examination. I found it no easy task to locate the exact dip and horizon of these planes of movement: in fact, the beds have been more crushed and rolled out than even Prof. Bonney himself, I think, imagined. Not only are there undoubted lines of movement between the crystalline rocks and the beds of rauchwacke, but, for some distance from the schists, fragments of the latter rock have been torn off and incorporated in the calcareous beds. In the lower part of the schists again, between the two lakes, eyes of calcite and dolomite have been rolled out and included in the crystalline schists; and it is possible to collect from the western end of Lago Ritom a series of specimens, ranging from pure rauchwacke to a foliated rock consisting of alternate layers of rauchwacke and schist. The whole process must have been analogous to what I have seen taking place in the case of advancing Arctic glaciers. Here not only are thrust-planes formed by the continual retardation of the lower layers of the ice, but, owing to the presence of shear-planes, fragments of the underlying material are dragged out along them and arranged in a roughly-stratified manner throughout the ice; many of these are even raised by this process for considerable distances above their source of origin.

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[1] Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 187.

We may, I think, then conclude that, so far as the valleys in which the lakes lie are concerned, their formation has been determined by the presence of thrust-planes, and that, in the case of the valleys in which the three larger lakes occur, the effect of these thrusts was emphasized by the introduction of wedges of softer rock.

The overdeepened portions of the valleys in which the lakes occur still, however, remain to be accounted for. They cannot, of course, be due to ordinary mechanical erosion by the present stream; but the special character of the rocks seems to suggest that the chemical action of water may have manifested itself in an unusual degree, owing to the relatively-greater solubility of the calcareous rocks. Analyses of three samples of the rauchwacke have kindly been made for me at University College (London) by Miss Edith Goodyear, B.Sc. These were collected from the barriers of rauchwacke rising from the southern end of Lago Tom and the western end of Lago Ritom respectively. I have added for comparison a fourth analysis, made by Dr. Grubenmann, of the same dolomite where it crosses the Val Canaria.[1]

	I.	II.	III.	IV.
CO_2	39·21	39·30	41·88	44·96
CaO	45·61	45·41	41·90	40·12
MgO	4·10	3·83	8·80	11·96
SiO_2	—	1·19	—	—
Fe_2O_3	1·34	2·01	1·28	0·42 FeO
Insoluble residue	8·10	7·87	6·04	1·96
Totals	98·36	99·61	99·90	99·42

No. II is from the broken-down underground channel described above. It was especially selected, on account of the relatively-large amount of green mica which it contained; while No. I is an average sample of the rauchwacke. No. III was collected from the cliff of rauchwacke cropping out on the east side of Fongio.

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[1] See Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 230.

The solubility of the rock is shown by its crumbly and cavernous character where it is exposed at the surface (see Pl. XII, fig. 1), and by the fact, mentioned above, that the surplus-water from Lago Tom, instead of finding an exit over the rauchwacke, dissolves its way underground and reappears exactly at the junction of the rauchwacke with the underlying insoluble schist.

Experiments prove that the rock is rapidly disintegrated by water containing carbon-dioxide in solution. Miss Goodyear finds:—

	Per cent.
Soluble in cold dilute hydrochloric acid	75·8
Soluble in hot dilute hydrochloric acid	92
Soluble in $H_2O + CO_2$	11 in 45 hours.

Assuming the difference between the solubility in hot and cold acid to be due to dolomite, the composition of the rock would be as follows:—

$CaCO_3$	73·4
Dolomite	16·2
Fe_2O_3	1·3
Insoluble residue	8·1
	99·0

Microscopic examination shows how this solubility is assisted by the granular structure of the rock, which readily falls to pieces so soon as the crystals of calcite are dissolved.

Being impressed, when sounding these lakes, with the possibility of their having originated from solution of the rauchwacke, I dredged several samples of the deposits from the floor of Lago Tom and Lago Cadagno. These were taken from their southern sides, where the deposit overlies the outcrop of the rauchwacke. They consist, in both cases, of coarse fragments of various minerals mixed with a fine white micaceous sand. The coarser fragments are composed of quartz, garnet, actinolite, and mica, derived from the crystalline schists above, and washed into the lakes by streams from the north. The finer material, after sifting through a sieve of 80 meshes to the inch, consisted of little rounded grey grains, together with a few flakes of mica, etc. On boiling in dilute acid, the former dissolve readily, and prove to be dolomite-grains, which have fallen on to the floor of the lake after the solution of the calcite and the disintegration of the rauchwacke. This finer material, therefore, represents the less-easily soluble residue of the rauchwacke. The collection of the dolomite-grains into one sieve is due to the wonderfully-uniform grain of the recrystallized rock. With the view of further testing the solubility of this rock, I collected samples of the water from Lago Tom and Lago Cadagno.[1] The samples were collected where the water flowed out of the lakes. These are found to contain total solids :—

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[1] Taken after a week of very heavy rain.

Lago Tom	·0733 gramme per litre.
Lago Cadagno	·1260 „ „

A qualitative analysis showed that the solid salts consisted of lime and magnesia, with a little iron and alumina. In the case of Lago Cadagno especially, a great deal of sulphuretted hydrogen was discharged when the mud was disturbed on the bottom of the lake, and the sounding-line and plummet, when drawn to the shore, always smelt strongly of this gas. The same phenomenon was noticeable in the case of Lago Ritom, but I never noticed the presence of sulphuretted hydrogen in the mud from the floor of Lago Tom.

There can be little doubt, I think, that the presence of this gas in such quantities in the deposits of Lago Ritom and Lago Cadagno, and its absence from Lago Tom, must be attributed to the presence of fishes in the two former lakes and their absence from the last-named. While the two former are stocked with trout, all attempts to rear trout in Lago Tom have failed, and this failure is attributed by M. Lombardi to the presence of lime in its waters.

[In this connection the investigation of MM. André Delebecque & Ernest Bourcart on the waters of certain Alpine lakes is full of interest.[1] M. Bourcart finds in the bottom-waters of Lago Ritom 2·365 grammes of dissolved salts per litre, including the following salts :—

		Grammes.
SiO_2	=	0·010
CaO	=	0·737
MgO	=	0·1962
SO_3	=	1·3767
K_2O	=	0·0042
Na_2O	=	0·0027
$Fe_2Al_2O_3$	=	0·0012

The surface-water, on the other hand, contains only 0·140 gramme per litre of dissolved salts; and the three affluent streams from Lago Tom, Lago Cadagno, and the Val Piora contain a mean of 0·139 gramme per litre (*op. cit.* p. 937).

The authors are probably right in concluding that the great increase in dissolved salts found in the bottom-waters is due to underground springs, which enter the lake through the soluble rauchwacke. It might be urged that the salts had accumulated at the bottom by degrees, owing to the formation of ice in winter and the consequent concentration of the salts in the surface-water, which would thus have its specific gravity increased, and, being at the same time cooled down, would be compelled to descend. An interesting point in this connection is, however, brought out by the temperature-determinations made by these authors at different depths. They find that anomalies of temperature occur, similar to those discovered by M. Venukoff in the Black Sea. With a surface-temperature of 13·2° C. a gradual decrease takes place until a depth of 33 feet is reached, where a minimum temperature of 5·1° is found. Below this, the temperature gradually increases until the bottom is reached, where, at a depth of 144 feet, the temperature is found to be 6·6° C. This rise of temperature in the bottom-waters of the lake appears to me to point to underground springs as the cause of concentration of salts in the lower layers, rather than to the sinking of concentrated surface-water in winter.

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[1] Comptes Rendus Acad. Sci. Paris, vol. cxxxix (1904) pp. 936 *et seqq.*

Another interesting point is brought out by the presence of a large quantity of sulphuric acid in the deepest layer of Lago Ritom. The authors attribute the presence of this acid to the solution of gypsum, but there is no bed of gypsum recorded among the rocks which crop out round the lake. It will be seen, however, that the bed of rauchwacke shown on Dr. K. von Fritsch's map, as running from Pian' Alto into the Val Canaria, includes large beds of gypsum where it thickens out to the west; and that, if Lago Ritom occupies the site of a similar 'eye' of rauchwacke, it is highly probable that this eye includes beds of gypsum as well as rauchwacke, for it lies along the same line of strike. In this connection, the total absence of sulphuric acid from the waters of Lago Tom is a highly-suggestive fact.

The analyses, then, of MM. Delebecque & Bourcart seem to confirm the idea that Lago Ritom owes its origin, in part at all events, to solution.]

Although the presence of these lakes appears to depend chiefly on the structural peculiarities described above, accompanied, in some cases at all events, by solution, there is one remarkable feature in the drainage of the district on which I have only briefly touched: I refer to the way in which Lago Ritom is surrounded by hanging valleys. Not only is this the case with all the three streams flowing into it, but it is still more marked in the case of the La Foos torrent, which flows out of the lake, and carries away the whole of the drainage of the Val Piora. This torrent plunges by a series of cascades 2700 feet down into the Ticino River, at an average slope of 1 in 2·6. As I have shown elsewhere, this torrent forms one of a series which drain from hanging valleys into the Ticino as a consequence of the overdeepening of the main valley. While other valleys, such as the Val Canaria, have adjusted themselves to the Ticino, the Val Piora has been prevented from doing so by the presence of the lake, which has arrested erosion by holding up the solid particles on its floor.

Let us trace the history of the Piora drainage a step farther back.

A glance at a model or map of the district shows that La Foos is obviously not the natural outlet of the present Val-Piora drainage: it is evidently either a 'stolen' outlet, due to some disturbance in the original flow, or the relics of an earlier drainage before the present Val Piora came into existence, for it turns off at right angles to the general line of the valley. I think, however, that it flowed over its present exit previous to the formation of the lakes, and that their formation may be connected with the diversion of the drainage into the 'Foos' channel.

As the valley is entirely rock-bound, the diversion cannot be due to the blocking of an old outlet at the western end; it must, therefore, be due to the direct encroachment of the Foos on the Piora watershed, through which it has cut. This can only have happened if the Ticino Valley were more rapidly overdeepened than the valley into which the original Piora river drained. Obviously, therefore, it did not drain directly into the Ticino; but where else could it drain? There are only two answers to this question. One is, that it drained over the col between Fongio and Pian' Alto, at the western end of Ritom, into the Val Canaria, as suggested by Prof. Bonney; the other is, that it flowed eastwards, and not westwards, over what is now the Passo del Uomo, and that the drainage to the west of this pass has therefore been reversed. This latter explanation would account, not only for the hanging valley of La Foos, but also for those at the eastern end of Lago Ritom and below Lago Tom. It is probable, however, that there were several stages in this process, which appear to have been as follows:—

(1) Before the present depression of the Val Piora existed, the general drainage of the district would be very different from that of the present day, and a stream rising on the Camoghè range may perhaps have flowed eastwards into the Medelser Rhein in Pliocene times. About this, however, it is difficult to be certain, as no relic of that period remains.

(2) The overdeepening of the Ticino Valley, which then appears to have taken place, may have enabled a stream from the Val Canaria to cut back over what is now the Fongio col as far as the head of the present Tom Valley. This diversion, although unconnected with the formation of the lakes, appears to be indicated by the present depression between Fongio and Pian' Alto.

(3) This overdeepening by the Ticino, postulated above, would enable the Foos, which then rose on the northern slope of the Val Ticino, to cut back its head-waters until it captured the drainage of the present Tom Valley.

This would naturally result from the circumstance that, whereas the Foos drained directly into the overdeepened Ticino Valley, the stream over the Fongio col drained indirectly into that valley, through the Val Canaria, which, at that time, would not have yet adjusted itself to the Ticino level. Relics of the drainage as it existed at that time are clearly visible at the present day, not only in the Foos Valley draining northwards and southwards from the col between the Punta Nera and the Taneda to the Ticino, but also in the low watershed (not yet completely destroyed) running parallel with this valley from the Taneda, and now separating Lago Tom from Lago Cadagno.

(4) This watershed was next gradually cut through by an eastern tributary of La Foos at its weakest point, namely, the point occupied by the rauchwacke along the line of the present Lago Ritom, and this tributary extended farther and farther to the east, to form the present Val Piora. On this supposition, namely that the Foos Valley existed before the Val Piora, it is easy to account for the fact, otherwise difficult of explanation, that the present drainage from the Val Piora turns at right angles where it discharges itself into the Ticino Valley.

(5) An uplift of the range to the west, possibly connected with the melting-

off of the ice, caused a diminution in the flow of the drainage in this valley, and the solution of the rauchwacke gradually produced a hollow extending as far as the limits of this calcareous rock. Thus at the present day, as shown above, Lago Ritom is bounded on the north and north-east by steep walls of crystalline schist, while its southern margin is formed by the dip-slope of the underlying gneiss. The same cause may reasonably be assumed to have operated in the case of Lago Tom and also of Lago Cadagno.

In this survey of the physical history of the district, I have not included the formation of the two upper lakes situated near the watershed, namely Lago Scuro and Lago Taneda. These lakes are, indeed, difficult to account for on any hypothesis. One fact, however, appears certain, namely, that to whatever they owe their existence, their occurrence along the junction of two dissimilar rock-masses must have been the prime determining cause.

III. The Lago-Tremorgio Group.

This consists really of several groups of tarns scattered along both sides of the southern watershed of the Val Levantina. They lie for the most part along the outcrop of the calcareous schists, in some cases exactly along the junction of these rocks with the gneiss.

Lago Tremorgio.—I will take this as a type of the lakes of this group, as it is not only the largest, but, I think, the most interesting, and certainly the deepest, of those occupying the southern slopes of the Val Levantina. It is also one of the lakes enumerated by Prof. Bonney among true rock-basins. It lies at a height of 5996 feet above sea-level, and 2880 feet above the Ticino. It is nearly circular in shape, having a maximum diameter from north-east to south-west of 853 yards, and a width at right-angles to this of 787 yards.

The overflow escapes through a narrow waterworn notch at the north-eastern corner, the lower few feet of which appear, as Prof. Bonney remarks, to be artificial, and falls into the Ticino by a series of cascades; in winter, however, this stream is dry. With the exception of this channel, the lake is entirely surrounded by steep hillsides (see Pl. XIV, fig. 1). All round the southern shore the lake is bounded by precipitous rocks, the upper 500 feet forming an inaccessible cliff, the average slope from the water's edge being 55°. The slopes from the northern and western walls are gentler, but even these show an inclination of 30° to the point on the northern watershed which is marked 2047 m. in the Swiss Government map.

The lake therefore lies in a funnel-shaped rock-basin, the rim of which runs about 700 feet above the lake, except where it is broken through at the exit: the average slope of the sides of the funnel being about 45°. In fact, if we consider a funnel having this slope to be tilted towards the north-west, we get an exact representation of the shape of the basin. Prof. Bonney aptly compares it to an armchair, which it certainly resembles, only the arms curve round in front till they nearly meet, so that it could only be sat in with the legs crossed. It is obvious that, in considering the origin of the lake, we must take into account the whole of this funnel before it was breached at the exit, as it is probable that the water of the lake once stood at a much higher level before the notch had been eroded and cut down to its present depth.

The basin does not lie in the path of any valley, for, with the exception of a small stream coming down a gully from Ponc. Tremorgio on the west, the only drainage that it receives pours over the southern rim of the funnel from the Campolungo Alp.

This stream originates in a small lake, apparently a rock-basin, lying high up at 7436 feet above the sea, north of the Campolungo peak. Local tradition has it that this lake is unfathomable, which probably means that it is more than 20 feet deep. The stream from this lake appears originally to have flowed over the Campolungo Pass westwards into the Val Maggia, and to have been afterwards diverted into the Lago-Tremorgio drainage, as the valley was carved out of the dolomite in which the Campolungo Alp lies. The lake cannot, therefore, by any possibility be regarded as occupying an overdeepened pre-Glacial valley, and it resembles nothing so much as a large swallow-hole.

The greatest depth of the lake is said to be 120 metres (394 feet) near the centre. I give this on the authority of Mr. Fraser, an engineer residing at Lugano, who took soundings from a raft. Unfortunately, my attempts to sound this lake were frustrated on two occasions; the first time by bad weather and fogs, and the second time, after partly completing the soundings, the line was so repeatedly cut by sharp submerged reefs that I was obliged to abandon the endeavour, the time at my disposal preventing a third attempt. The discovery of these reefs, however, is not without bearing on the origin of the lake. From the soundings which I obtained, the depth appears to increase very regularly from the western corner towards the centre; and if this general slope continues, it would give a depth of 250 feet at the centre of the lake. This is not the case, however, near the northern shore, which falls steeply from the outlet. The lake is excavated in the calcareous schists. The reefs running out from the south-western corner contain 'eyes' of massive andalusite with a hardness of 7½.

The lime in the calcareous schist is chiefly present in the form of eyes of crystalline calcite, which measure frequently several inches across, and crumble at the touch; and, where portions of the rock were obtained from the edge of the lake, these eyes were frequently represented by holes, the calcite having been entirely or partly dissolved out.

The lake cannot be considered as the result of glacial erosion. The production of a funnel-shaped hollow 1000 feet deep, with an upward slope of 30° on the exit-side, cannot have been produced by ice-action; and the origin of the hollow in which the lake lies must, I think, be attributed to chemical solution. Two important facts seem to bear on this hypothesis; one is the way in which the level of the lake sinks several metres below its outlet in winter, and the other is the occurrence of springs (issuing from the precipice below the lake) which continue to flow all the year round. This latter circumstance has been made use of by the engineers of the St. Gotthard Railway, who obtain the water for their locomotives, not from the overflow-torrent from the lake, but from these permanent springs. The solution of the calcareous portions of the schist might cause the funnel-shaped hollow in which the lake lies; but it is also possible that the dolomite which occupies the Campolungo Alp may have been folded in under the lake, as shown in the very suggestive section to the west of the Campolungo Pass (see Pl. XIII, fig. 2). If this fold be continued underground, it must certainly pass beneath the lake. The fact that the outcrop of the dolomite strikes across the schist, and terminates abruptly at either end against the gneiss, only to reappear as an isolated outcrop in the Val Piumogno on the east, is a very suggestive one, as it emphasizes once more the inconstancy of these eyes of dolomite and their fortuitous occurrence among the crystalline rocks.

Of the remaining lakes of this group, those scattered along the southern side of the Ticino watershed are the most important. They drain either directly into the Val Maggia, or indirectly through the Val Bavona. The Lago di Naret has a wedge of crystalline limestone running across it, while the Lago Sciundrau is situated on the junction of dolomite and gneiss. The Laghetti or lakelets to the east of Lago di Naret, again, lie along the junction of the calcareous schist and the gneiss; their origin would appear, therefore, to be similar to that of the lakes of the Val Piora. But, without soundings and detailed investigation, it is best to leave their origin an open question for the present, as they will well repay further investigation.

IV. The St. Gotthard Lakes. (For topographical map, see p. 186.)

At the northern end of the Canton lie a small group of lakes near the summit of the St. Gotthard Pass. Of these, the Lago della Sella and the Hospice-tarns drain southwards by the Val Tremola to the Ticino, while the Lago di Lucendro, the Lago Orsirora, and the Lago Orsino supply the headwaters of the infant Reuss.

The Hospice-lakes are small rock-pools, which owe their existence partly to artificial means, having been in some cases dammed by the old monks of the Hospice to serve as fishponds, which still yield fine trout. They are also partly due to the highroad embankment thrown across the swampy summit of the pass. The portion of the largest lake north of the road is only about 16 feet deep; the southern portion appears to be deeper, but I should think cannot exceed 50 feet in depth.[1] Of the others, the Lago di Lucendro is by far the most important.

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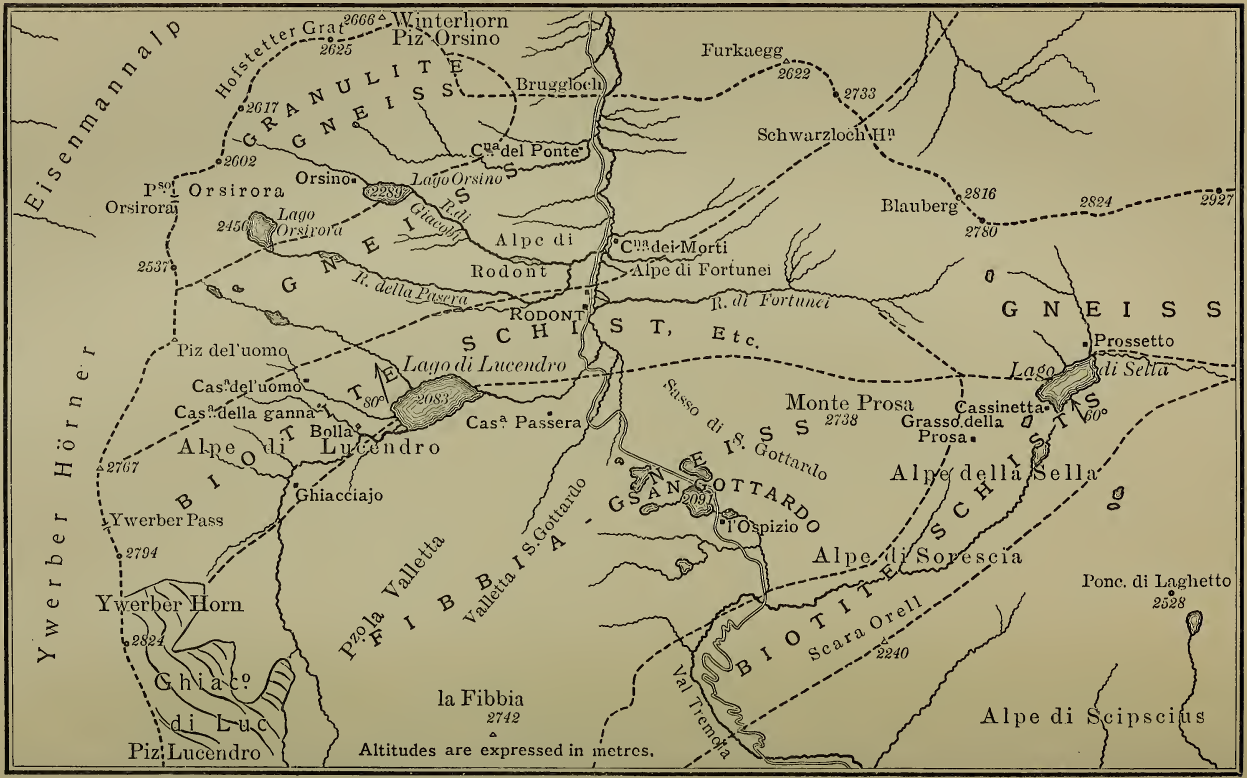
[1] The deepest sounding met with.

Lago di Lucendro (see Pls. XIV, XV, & XXI).—This lake lies at a height of 6832 feet above sea-level, in the valley between the Piz Lucendro and the valley of the Gotthard Reuss, above Hospenthal. In shape, it is roughly a parallelogram, with the longer diameter running north-east and south-west. The greatest length from east to west is rather more than 765 yards; and the greatest width is 306 yards, the average width being about 270 yards. The water is, to a slight extent, retained by the supports of the bridge at the exit. The greatest depth met with was 126 feet; and the axis of greatest depth, as shown in the bathymetrical chart (Pl. XXI), lies parallel to the length of the lake, and rather nearer the western than the eastern bank. The prolongation of the contours along this line, into the bay at the western end, is an interesting feature of the chart. The valley in which the lake occurs is occupied at its upper end by the Lucendro Glacier. The drainage of this glacier is carried off by three streams, which form the source of the Reuss and constitute the chief feeders of the lake. This also receives the overflow from the little lake to the north-west, situated at the eastern base of the Piz del Uomo, and several streams which drain the cirque-like wall on the south and west of the lake. The lake occupies a rock-basin, and lies along the junction of the Fibbia gneiss and the biotite-schist, the latter occupying the northern bank. A good section of the schist is seen along the north side of the lake, about 500 yards from the bridge. Here the schist is much crushed and contorted, and penetrated by veins of granite. If the veins are offshoots of the Fibbia gneiss, the lake must lie absolutely along the junction of the two rocks: as in most other cases, however, the actual shoreline is modified by scree and delta-material.

With regard to the origin of this lake, there is no evidence of solution having played any part in its formation. On the other hand, the promontory of solid rock jutting out into the lake from the exit does not seem consistent with excavation by ice, as usually understood; and the presence of this lake along the junction of a massive granitic gneiss and a mica-schist points undoubtedly to the conclusion that here again the main determining factor for the existence of the lake has been the occurrence of a line of weakness along the contact between a hard and a comparatively-soft rock, giving rise to differential weathering. The whole district, however, has been intensely glaciated, and a prolongation of the Lucendro Glacier must formerly have passed over the site of the lake. It is quite possible that this glacier removed the weathered surface of the disintegrated schist, while it made but slight impression on the harder granite. The uneven surface thus produced would cause the accumulation of water, so soon as the glacier withdrew from the lower part of the valley.

The origin of Lago Orsirora and Lago Orsino, on the north of Lago di Lucendro, appears to be due to the same cause, as they lie along the junction of the gneiss on the south and the granulite on

Map of the St. Gotthard lakes, on the scale of 1 : 50,000.



This broken line indicates the Cantonal boundary.

the north, while the smaller tarns are obviously dammed by loose material.

Lago della Sella.—This lake forms an irregular sheet of water lying in the Val Torta, east of Monte Prosa, at a height of 7320 feet. It consists of a shallow lake on the north and a smaller pond on the south, united by a rocky ditch about 180 yards long,—the whole giving the idea of a flooded river-system (see Pl. XV, fig. 2). The actual exit is dammed by a landslip, although the lower sheet is certainly a rock-basin. The northern and western shores of the main lake are formed of gneiss, while biotite-schist occupies the southern and eastern banks. This schist resembles that which forms the northern bank of Lago di Lucendro, and is penetrated by similar granite-veins.

The strike of the schist is north-east and south-west, parallel with the longer axis of the lake, the dip being some 60° north-westward. The schist forms a rocky ridge running into the southern end of the lake. This rises to the surface again in two islands, united under water by shallow depressions only 12 feet deep. Five rows of soundings were run across various portions of the lake, but the presence of the islands made a systematic survey difficult in the absence of a boat. The greatest depth met with was 25 feet, though it is possible that greater depths may exist near the upper end of the lake. The origin of the lake, however, seems to be due to precisely the same causes as Lago di Lucendro, namely, a line of junction between gneiss and biotite-schist along which unequal weathering has taken place, the more weathered portions having been removed by the ice, which must once have gathered in the Val Torta and flowed over the district now occupied by the lake. It is noteworthy, in this connection, that the stream now flowing into the lake from the Val Torta runs for over a mile exactly along the junction of the gneiss and the schist.

V. The Lago d'Elio.[1]

Although situated just beyond the political boundary, this lake belongs geographically to the Ticino basin. It lies at a height of 3025 feet, or 2378 feet above the Lago Maggiore, and is situated on the watershed between the Val Molino and the Val Vedasco. It occupies an elongated triangular depression in the gneiss between Monte Borgna and Monte Cadrigna. The lake has a length of 930 yards from north-north-east to south-south-west, and a width at the upper end of 300 yards, which forms the base of the triangle: from here it gradually tapers to the exit, which lies in the acute angle of the triangle at its southern end. The deepest soundings were met with about one-third of the distance from the upper end, the greatest depth being 134 feet, while depths of 74 and 75 feet were determined near the northern shore. The lake is, therefore, deepest towards its upper end, and shallows gradually to the exit. The northern shore is chiefly composed of loose material and boggy swamp, through which rise here and there hummocks of solid rock. The shape of the lake and the subaqueous contours, as well as the presence of loose material at the upper end, point to damming of a tributary valley by a landslip or moraine, and the reversal of the drainage over a gap in the watershed at its upper end. This view is borne out by the character of the exit, and also by the presence of a deep valley just beyond the accumulation at the northern end of the lake, into which it would apparently drain if the loose material were removed. There is, however, just a possibility that the lake may be to some extent rock-dammed.

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[1] A bathymetrical chart of this lake has been constructed; but it is unnecessary to introduce it here, as the lake has not been proved to be a rock-basin.

VI. General Conclusions.

The results arrived at by a detailed investigation of the tarns in the northern portion of the Canton Ticino may, then, be summarized as follows.

The lakes can, for convenience, be grouped under two heads:—

(I) Those (*a*) entirely, or (*b*) partly dammed by loose material.

(*a*) Lago Camoghè.	(*b*) Lago di Murinascio.
,, Lisera.	,, Lucomagno.
,, Pettano.	,, Orsirora.
,, d'Elio.	,, Orsino.
	St. Gotthard tarns.

(II) True rock-basins due to (*c*) solution, (*d*) differential weathering.

(*c*) Lago Ritom.	(*d*) Lago Scuro.
,, Tom.	,, Taneda.
,, Cadagno.	,, di Lucendro.
,, Tremorgio.	,, della Sella.

Those grouped under I (*a*) require no comment. Those under I (*b*), in so far as they are rock-basins, may possibly be due to differential weathering, either by frost or by ice. It is, however, difficult to ascertain what depth, if any, we are to consider as rock-basins in each case, but it cannot be a very great depth. Lago di Murinascio and Lago Lucomagno lie upon ledges dipping steeply into the scarp-face at the foot of precipitous cliffs, above which there is no possible gathering-ground for a glacier, unless the ice poured over the cliffs in each case from the north; but the cliffs are too steep for it to arrive, even then, in anything but a fragmentary state. Consequently, even Prof. Bonney's general concession, that the ice, as it descended from the ranges above,

> 'would impinge on the level floor, on which under these circumstances it might have some erosive force,' (Geol. Mag. 1898, p. 19.)

does not seem applicable here, as the corries would be filled with snow and protected from any bombardment of this nature. It is, of course, always possible that the slight irregular erosion of a few feet might have been produced by the ice collected in the cirque, as assumed by some authors to account for the formation of corrie-lakes in general; but it is difficult to realize the mechanics of the process, unless the ice found in these corries behaves rather differently from that of a glacier, and moves as a solid mass and not differentially as in a glacier. The lakes under notice are, however, comparatively unimportant; but, if any part of their basin is truly rockbound, they are difficult to account for, as they occur entirely in one rock-formation.

Rock-Basins.

II (*c*).—The chief lakes of the Val Piora are shown to lie along the junction of soluble calcareous rocks with gneiss or schists. Detailed soundings prove that the axes of greatest depth of these lakes coincide very closely with these lines of junction. Although the district must have been below the snow-line in Glacial times, there is very little sign of glacial action visible at the present day, and it is difficult to understand how ice can have taken any real part in the formation of the lakes.

Chemical evidence derived from analyses of the rauchwacke and from the composition of the water of the lakes, points strongly to solution having played a conspicuous part in the formation of these lakes. This is confirmed by the fact that, in the case of Lago Tom, the surplus-water does not overflow the containing barrier of rauchwacke at the exit-end, but, percolating into the heart of the limestone, reappears as a spring which rises exactly at the junction of the rauchwacke with the underlying schist.

Other evidence, such as the high percentage of dolomite-grains in the fine deposit forming the floor of the lake near the exit, evidently representing the less soluble portion of the rauchwacke, points in the same direction. In the case of Lago Ritom, it is shown that the whole of the western end of the lake is occupied by rauchwacke, although not so shown on the Swiss Geological Survey-map, and that the lake may be considered to occupy the site of a lenticular thickening of the calcareous beds similar to those which occur west and east of it along the same general strike. The marked increase in the amount of dissolved salts in the bottom-water of this lake, coupled with an equally-marked rise in temperature, are facts which point strongly to underground solution in the form of subaqueous springs; while the high percentage of sulphuric acid can only be explained on the supposition that beds of gypsum occur under this basin, similar to those found along the outcrop on the west and east.

Lago Tremorgio appears, from its characteristic pothole shape, to be also due to solution. It is situated on calcareous mica-schist, and the eyes of calcite in the schist are dissolved out from the rocks bordering the edge of the lake. It is also possible that the fold of dolomite, visible in the Campolungo Pass above the lake, may continue downwards to the lake-floor; and, if this should be the case, it would amply account for the basin by solution. The fall of the surface of the lake several feet below the exit in winter, and the continuous flow of springs which issue all the year round from the hillside below the lake, point also to solution as the probable origin of this lake. It does not appear to be possible to attribute this lake to glacial excavation, as it does not form part of a valley-system which could have been overdeepened by ice to produce the present basin.

II (*d*).—There remain four important rock-basins which are more difficult to explain. They resemble the foregoing group in the fact that they all lie along the junction of two different rock-types, so that, whatever the weathering agent may have been which finally produced the basin, the occurrence of the lakes in their present position seems certainly here again to have been determined by structural lines of weakness. Lago di Lucendro lies in the track of an extension of the Lucendro Glacier, and Lago della Sella also occupies a valley at the head of which a glacier-system still exists. It is possible, therefore, that differential weathering in pre-Glacial or inter-Glacial times, along the junction between the gneiss and the biotite-schist, may have caused an unequal removal of material by ice in Glacial times. This excavation does not appear to have been so much in the nature of digging, as of the removal of less resistant, possibly more weathered, material. This is shown by the marked convexity of the outlines of the gneiss even under water, by the presence of the rocky headland at the exit of Lago di Lucendro, and also by the occurrence of the islands of solid rock running through Lago della Sella. The two remaining lakes of this group, namely Lago Scuro and Lago Taneda, which occur within a stone's throw of the main watershed and occupy basins 140 feet deep, are certainly very puzzling: for, although they lie along the junction of schist and gneiss, the theory of solution does not appear to be applicable here. Had these lakes lain in glaciated valleys, they would have undoubtedly been considered by many geologists as typical ice-excavated basins. Their occurrence, however, a few metres below the watershed, as well as the presence of submerged reefs running round the southern end of Lago Scuro, seems to preclude the possibility of excavation by ice.

The lakes, then, of the Canton Ticino that have so far been examined, with the possible exception of the rock-pools of the St. Gotthard Hospice, do not seem to be due to ice-erosion in the generally-understood sense, if we adopt the most recent definition by Prof. James Geikie for this class of lake, as contained in the following statement:[1]

> 'Rock-basins of glacial origin differ from all others in the fact that they are totally independent of geological structure and the character of the rocks themselves.'

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[1] 'Structural & Field-Geology' 1905, p. 416.

EXPLANATION OF PLATES VII–XXI.

Plate VII (facing p. 168).

Map of the Piora Lakes, on the scale of 1 : 42,240.

Plate VIII.

View of Lago Ritom, looking east from the exit of the lake. It shows the contrast between the dip-slope of the gneiss on the southern shore, with its bays and headlands, and the escarpment of calc-mica and black-garnet schists forming the northern shore, down which cascade the three waterfalls from Lago Tom, Lago Cadagno, and the Val Piora respectively, counting from left to right, and terminating at the edge of the lake in their respective deltas. Pizzo Taneda forms the highest point along the skyline; while immediately to the left lies the col over to Lago Scuro, from which the photograph (reproduced in Pl. X) was taken. Below this, again, the notch in the middle distance marks a portion of the old Foos valley. On the skyline to the right of Pizzo Taneda is seen the gap occupied by Lago Taneda, the overflow from which can be discerned falling over the precipice of actinolite-schist into the Lago Cadagno, which lies immediately below. The Val Piora is situated on the extreme right of the photograph, behind the middle-distance escarpment, while Lago di Murinascio occupies the cirque above it.

Plate IX.

View of Lago Tom, looking towards the barrier of rauchwacke at the lower end, in which the water-channel leading into the rock is seen. The delta on the extreme right forms the upper end of the lake. The rauchwacke is seen occupying the centre of the picture. The skyline is composed of dip-slopes and escarpments, on the right and left respectively of each of the hills.

Plate X.

View taken from the col to the west of Pizzo Taneda (shown in Pl. VIII), looking across Lago Tom and the western end of Lago Ritom to the Val Levantina. The observer is looking straight down the old valley of La Foos, sections of which can still be seen below Lago Tom and at the exit of Lago Ritom. The distant range forms the watershed between the Val Levantina and the Val Maggia, and, although not visible, Lago Tremorgio lies on the flank of this range on the extreme left. The snow-filled lake in the foreground is scree-dammed, and lies on a ledge of actinolite-garnet-schist 1000 feet above Lago Tom.

Plate XI.

Panoramic view from the watershed between Lago Tom and Lago Cadagno, looking east. Lago Cadagno lies in the foreground on the left, and the gap immediately above it is occupied by Lago di Murinascio; while the delta at the head of Lago Ritom lies below on the right. The stream running into this down the wooded slope marks the isolated outcrop of rauchwacke at the eastern end of the lake. Up the centre of the picture runs the Val Piora, cut in the outcrop of the main mass of rauchwacke. Starting in the Pizzo Columbe (which forms the central peak in the skyline), this runs through Lago Cadagno, through the point from which the photograph was taken to Lago Tom, and away to the Val Canaria. The cattle-sheds in the foreground are built on the screes which dam the western end of the lake; while behind them, the moraine is seen forming its southern shore. The dip-slopes and scarp-faces formed by the actinolite-schists are well seen on the left in the middle distance; while the gorges, through which the rivers from Lago Cadagno and the Val Piora fall into the Lago-Ritom basin, are conspicuous in the foreground.

Plate XII.

Fig. 1 is a view of the barrier of rauchwacke at the lower end of Lago Tom. It shows the spring issuing from the rauchwacke at its junction with the underlying schist, which lies just beyond the photograph to the right. The cave from which the spring formerly issued is seen in the distance; while the honeycombed appearance of the weathered rock is well shown.

Fig. 2 is a photograph taken from the col looking down on to Lago Scuro. It shows the circular shape of the outcrop and the reefs of rock separating the lake into two portions, one of which is seen in shadow in the right-hand bottom corner. The exit of the lake, where it overflows into the Val Cadlimo, lies on the far side of the lake, on the extreme left.

PLATE XIII.

Fig. 1 is a view of the western end of Lago Ritom; the exit is masked by one of the promontories of gneiss on the left of the picture. The wooded slope behind the hotel is the 1930-metre hill. The lower portion, on which the hotel stands, is formed of gneiss; but the upper slopes, above and to the right of the house, are formed of the dolomite which sweeps round the end of the lake, also rising to form the col over the hill to the left and up to a line half way between the lake and the highest point—Fongio.

Fig. 2 shows the fold of dolomite in the Campolungo Pass. The dolomite strikes towards the observer on the left, dipping south-eastwards at a high angle. The mass of dolomite occupying the centre of the picture has been folded and faulted down to the right of the main outcrop, and it is possible that it is continued under Lago Tremorgio, which lies immediately below, just outside the right-hand corner of the picture.

The flat little valley is evidently eroded out of the dolomite; the stream flowing along it comes from the lake high up on the left, and appears to have been a somewhat recent diversion.

PLATE XIV.

Fig. 1 is a photograph of the lower end of Lago Tremorgio, showing the steep high cliffs surrounding the lake and the notch cut down at the exit. These cliffs continue all round the rest of the lake, becoming nearly vertical opposite the exit; and it is over this cliff that the stream, shown in fig. 2 of Pl. XIII, falls into the lake. The outcrop of the dolomite lies at the top of this cliff, to the right, outside the photograph.

Fig. 2 shows the Lago di Lucendro, seen from the upper end. On the right is the Fibbia gneiss, on the left the biotite-schist, the junction running down the centre of the lake. The bare convex surface of the glaciated gneiss at the lower end of the lake is well seen. The river in the foreground rises in the Lucendro Glacier, and forms the source of the Reuss.

PLATE XV.

Fig. 1 is another view of the Lago di Lucendro, taken from high up on the left bank. It shows the tongue of solid rock running back into the lake from the exit, mentioned in the text (pp. 185 & 190), and also the glaciated Fibbia gneiss near the exit. The dark rock in the lower part of the foreground is the outcrop of the contorted biotite-schist penetrated by granite-veins. In the distance is seen the St. Gotthard road, and beyond it the Hospice-lakes.

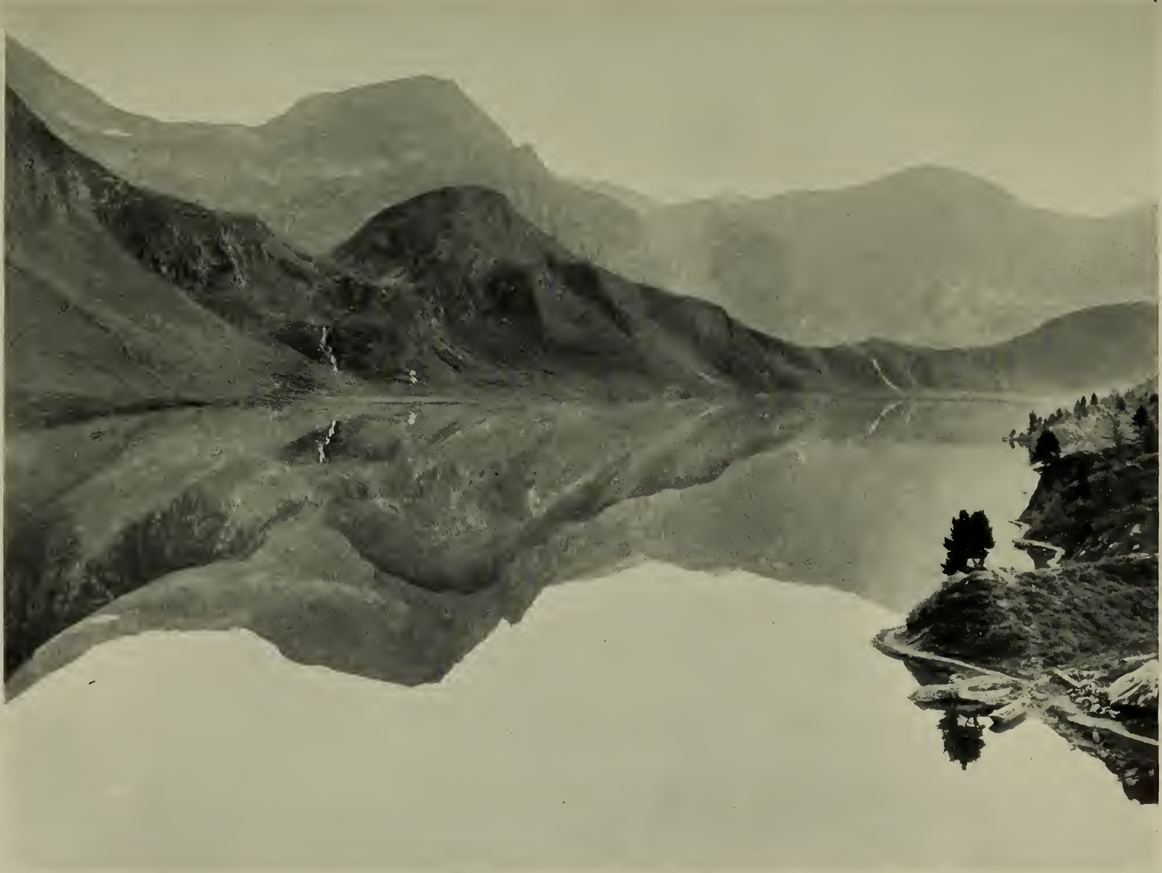
Fig. 2 is a view of the Lago della Sella seen from near the exit, showing the islands and illustrating its river-like character. The immediate foreground and the right bank are formed of biotite-schist, penetrated in places below the exit by veins of granite, where it borders on the Fibbia gneiss; while the greater part of the left bank is composed of gneiss. (See also map, p. 186.)

PLATE XVI.

Contoured map of Lago Ritom, on the scale of 20,000 : 3. *For* 'Airola' *read* 'Airolo.'

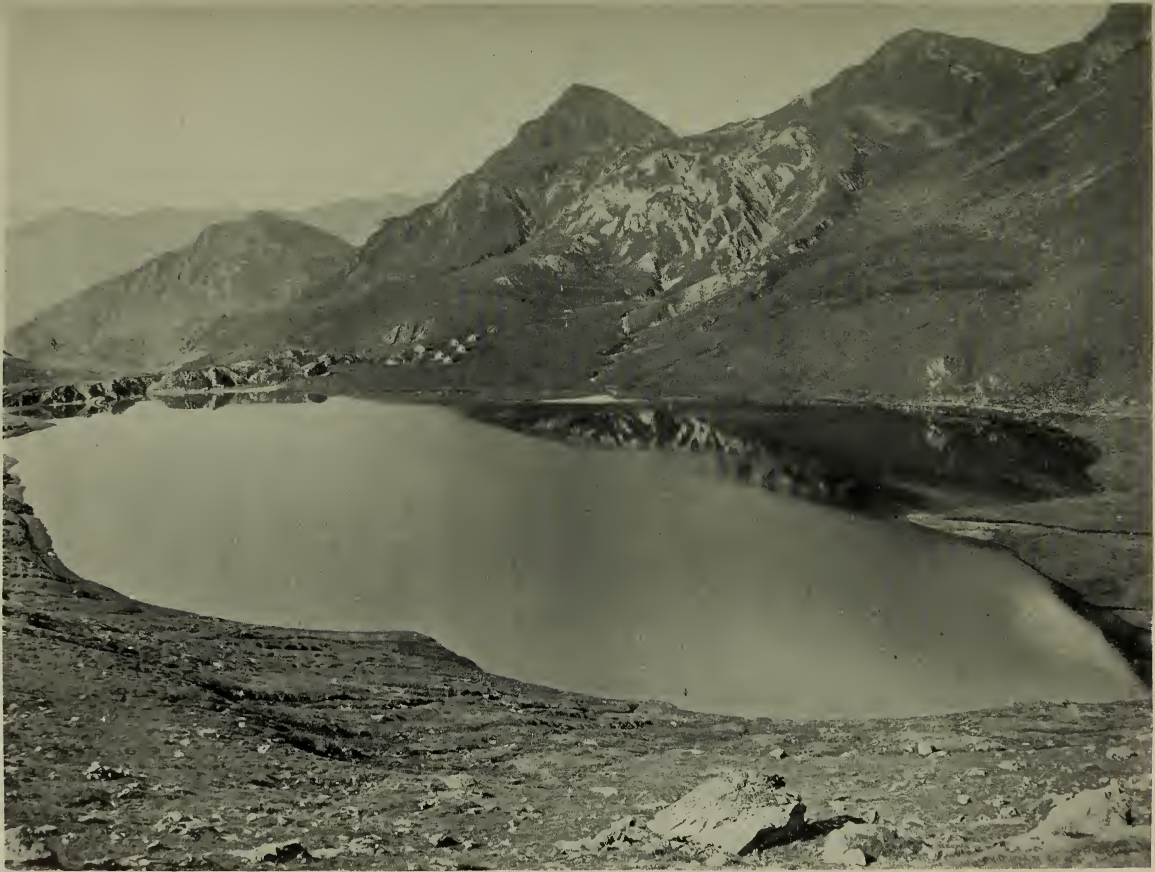
PLATE XVII.

Contoured map of Lago Tom, on the scale of 5000 : 1.



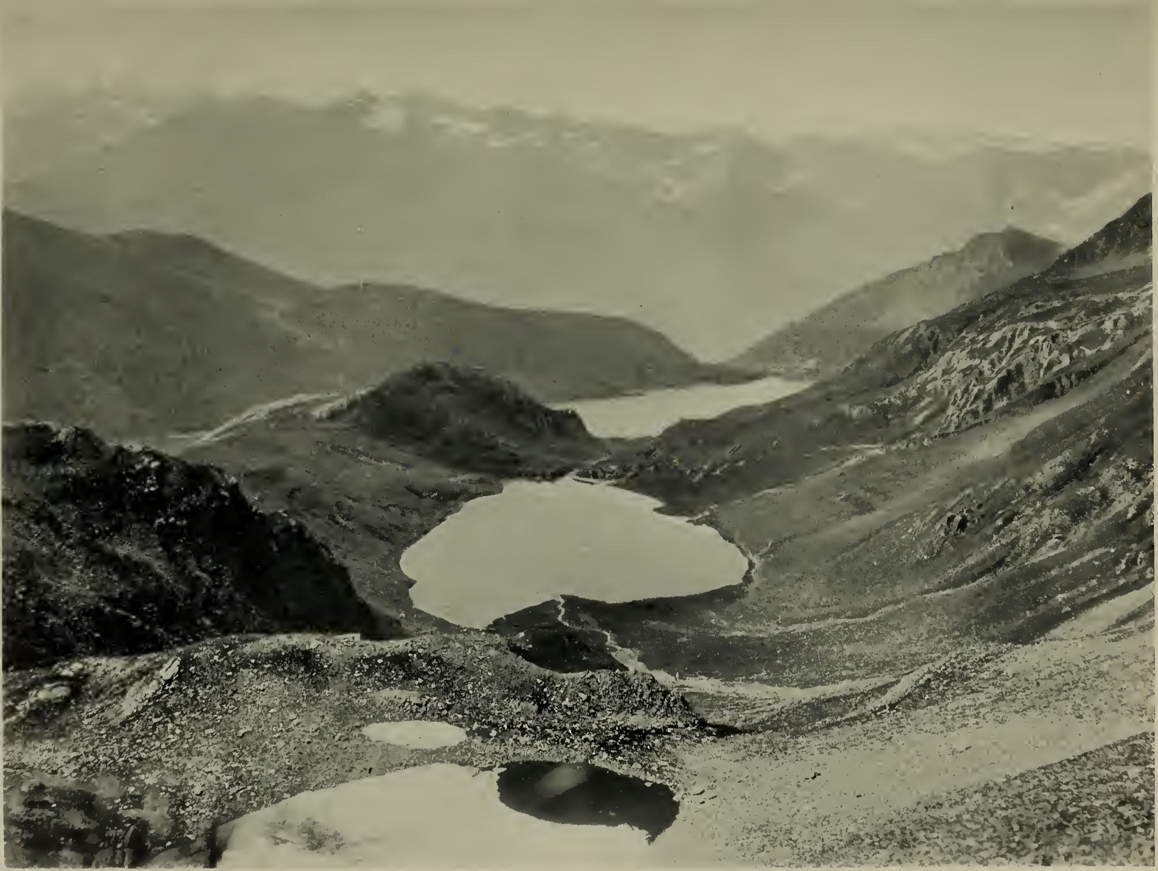
E. J. G., *Photo.*

LAGO RITOM SEEN FROM THE WEST.



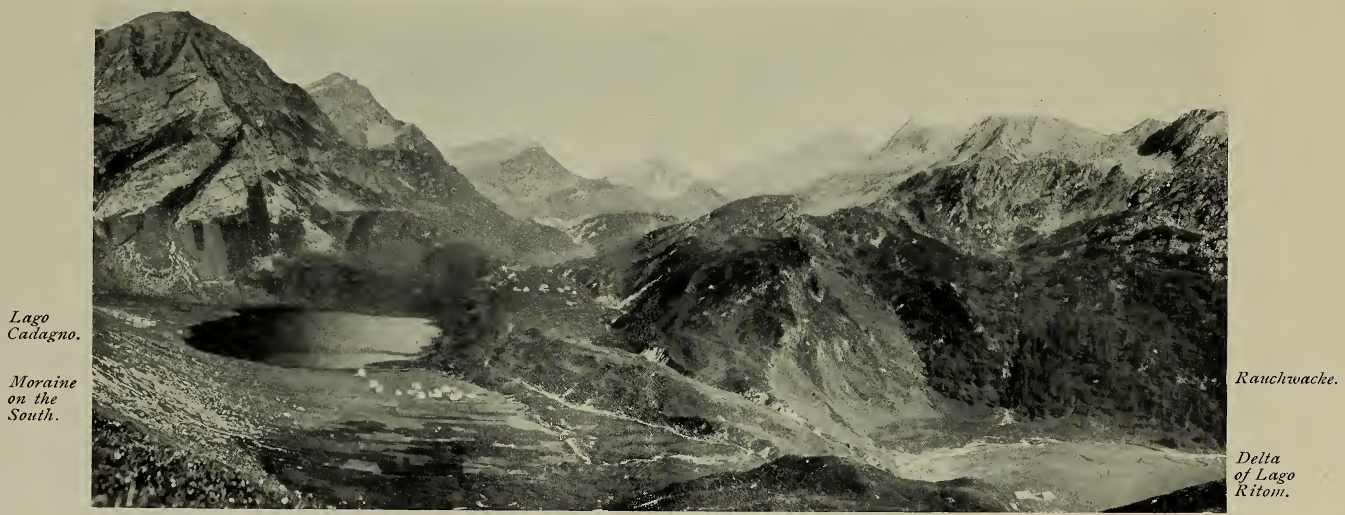
E. J. G., Photo.

LAGO TOM. VIEWED FROM THE NORTH-EAST.



E J.G., *Photo*

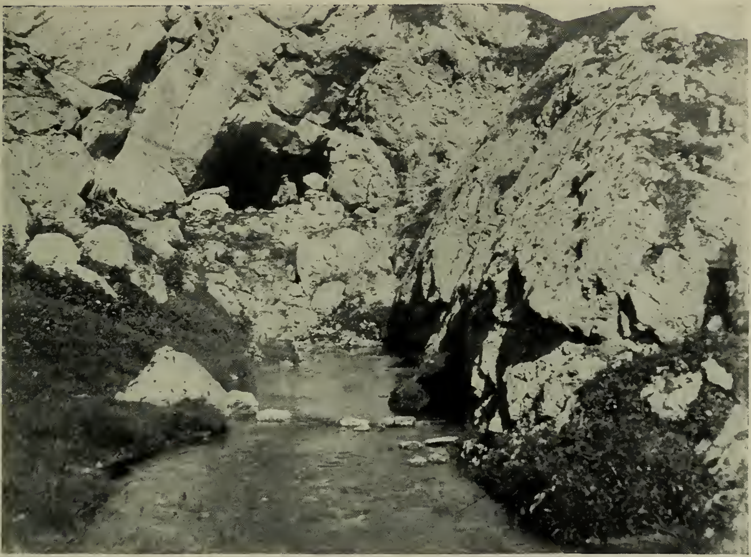
THE OLD FOOS VALLEY AND LAGO TOM, LOOKING SOUTH FROM THE WATERSHED.



E. J. G., Photo.

THE VAL PIORA AND LAGO CADAGNO, SEEN FROM ABOVE LAGO TOM.

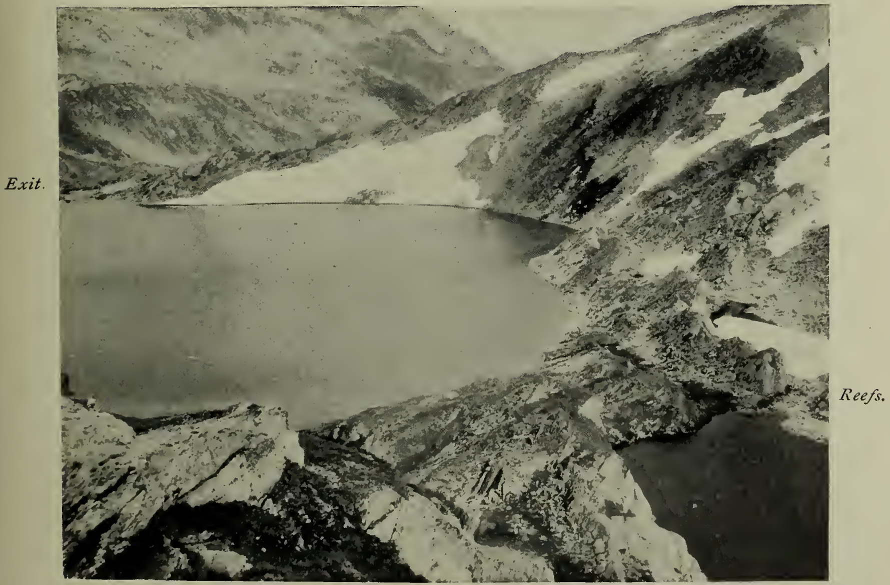
FIG. 1.



E. J. G., Photo.

SPRING ISSUING FROM THE RAUCHWACKE, BELOW LAGO TOM.

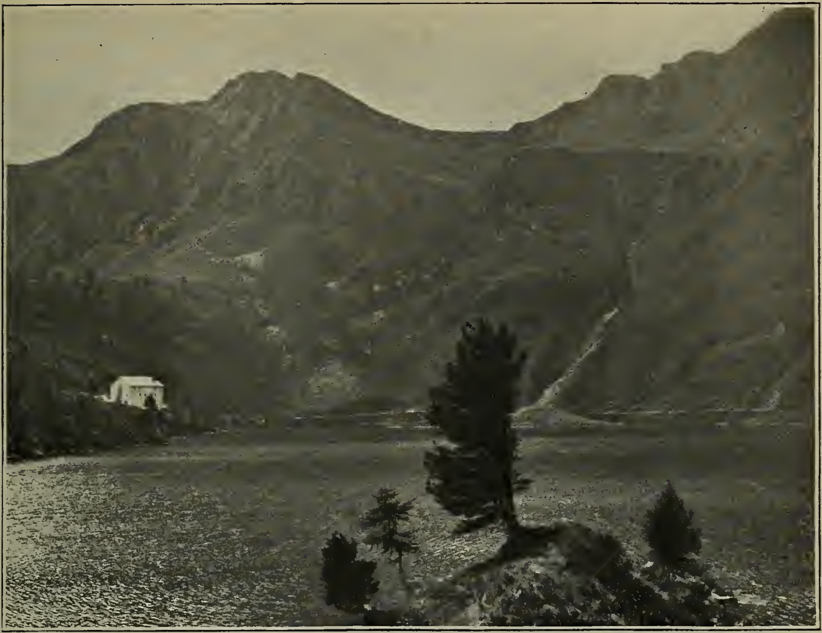
FIG. 2.



E. J. G., Photo.

LAGO SCURO, LOOKING NORTH FROM THE WATERSHED.

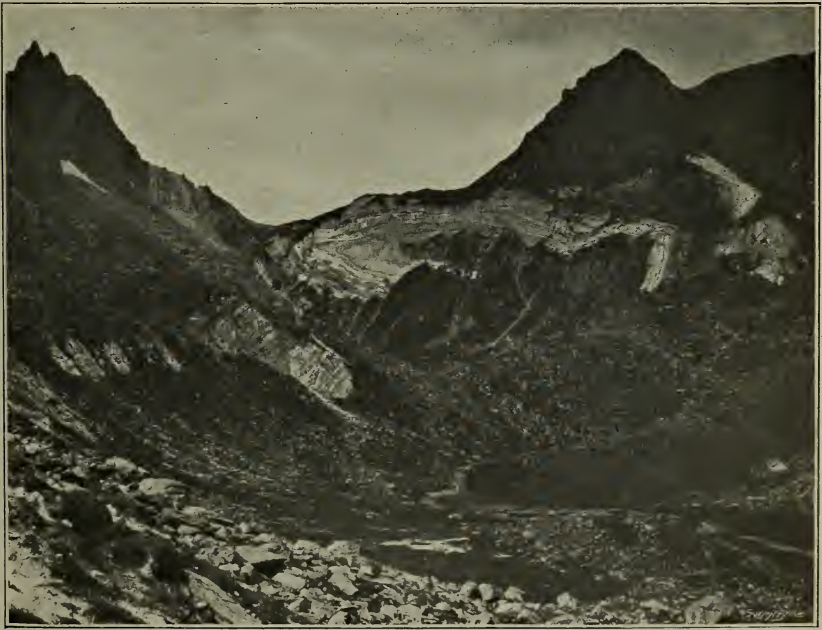
Fig. 1.



E. J. G. photo.

THE WESTERN END OF LAGO RITOM.

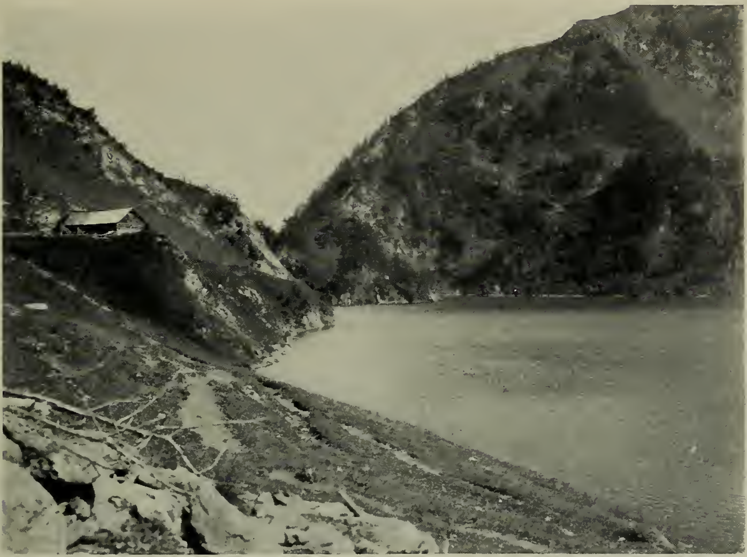
Fig. 2.



E. J. G. photo.

FOLD IN THE DOLOMITE, SOUTH OF LAGO TREMORGIO.

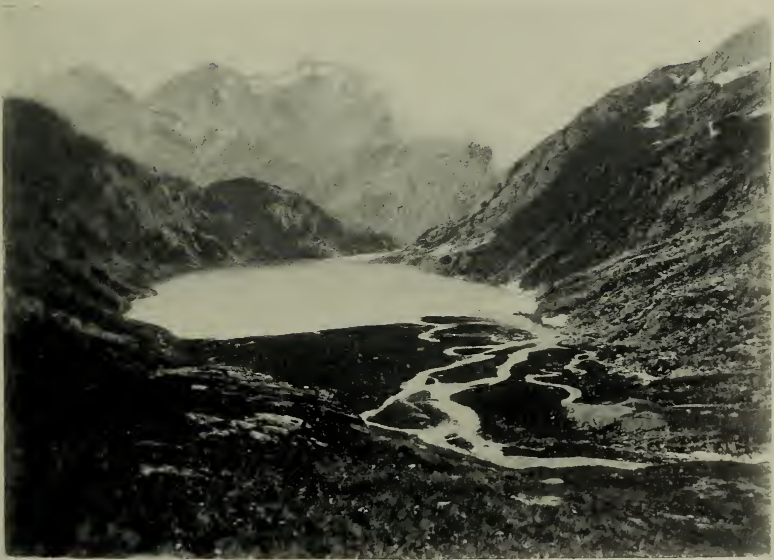
FIG. 1.



E. J. G., Photo.

THE EXIT OF LAGO TREMORGIO, SEEN FROM THE SOUTH-WEST

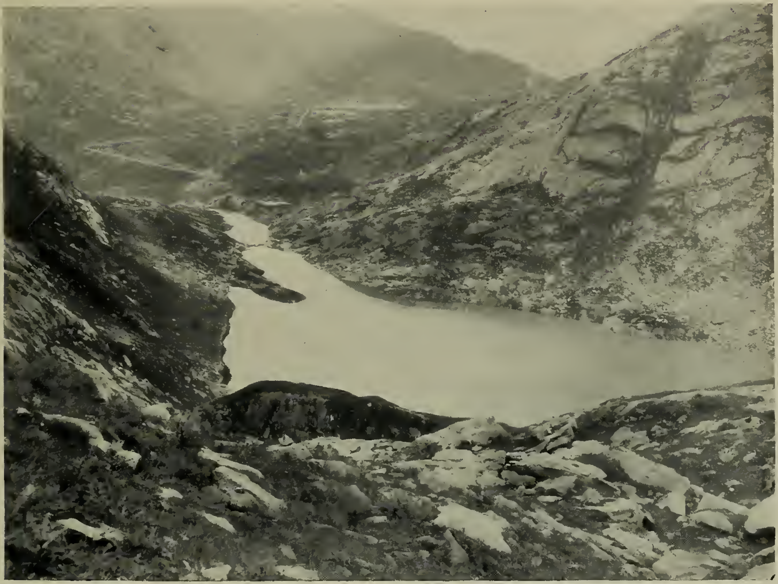
FIG. 2.



E. J. G., Photo.

LAGO LUCENDRO, SEEN FROM THE SOUTH.

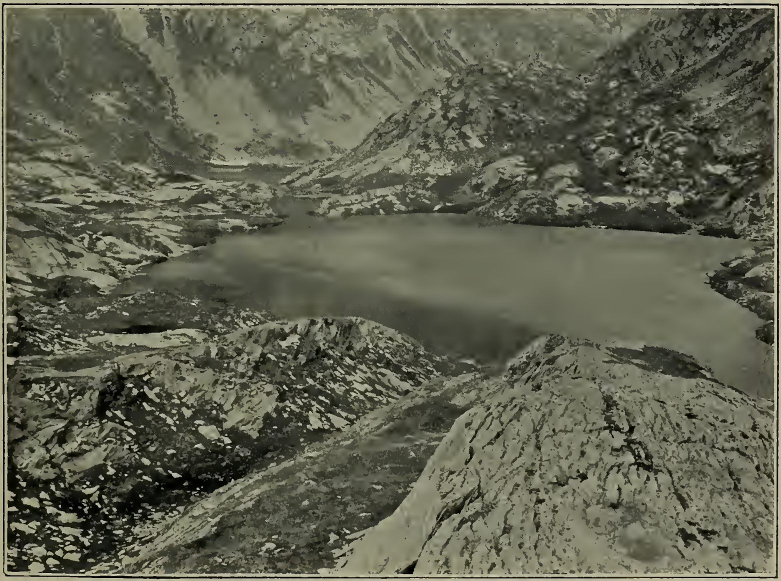
FIG. 1.



E. J. G., Photo.

VIEW OF LAGO LUCENDRO, SHOWING THE EXIT.

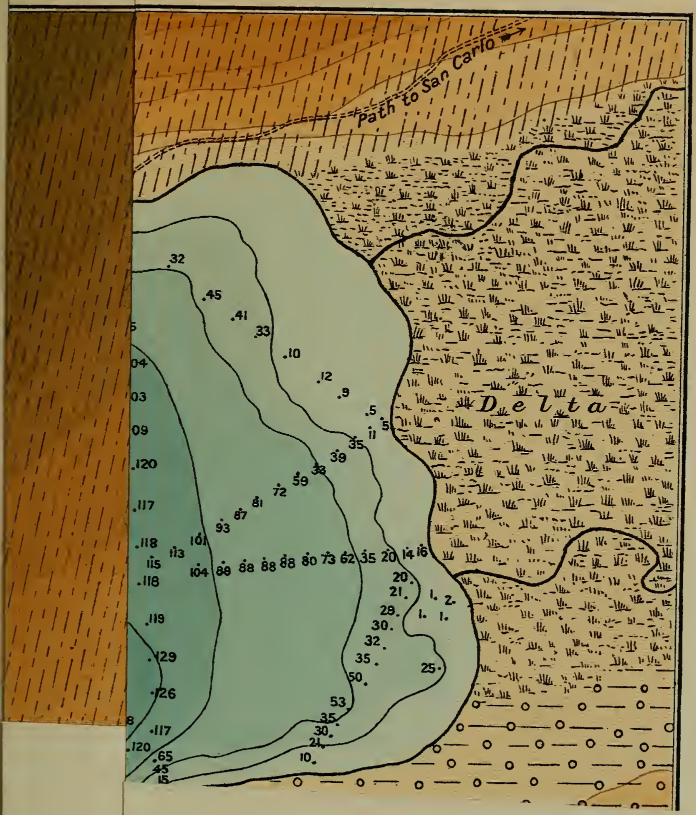
FIG. 2

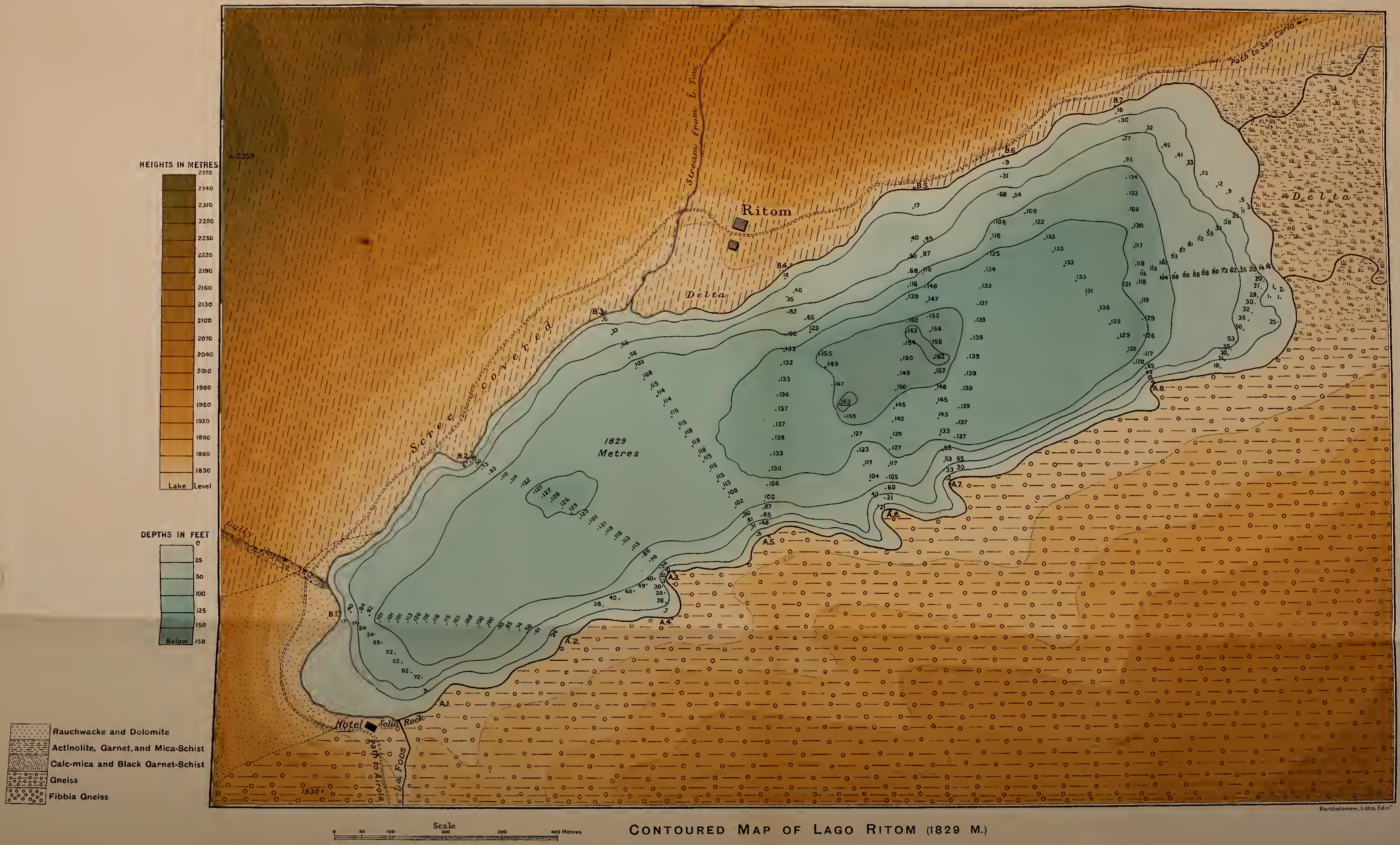


E. J. G., Photo.

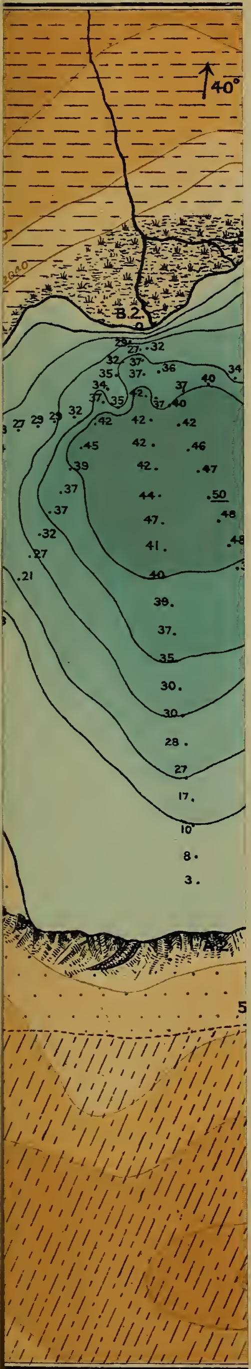
LAGO DELLA SELLA, SEEN FROM THE SOUTH-WEST.

QUART. JOURN. GEOL. SOC. VOL. LXII, PL. XVI.





CONTOURED MAP OF LAGO RITOM (1829 M.)



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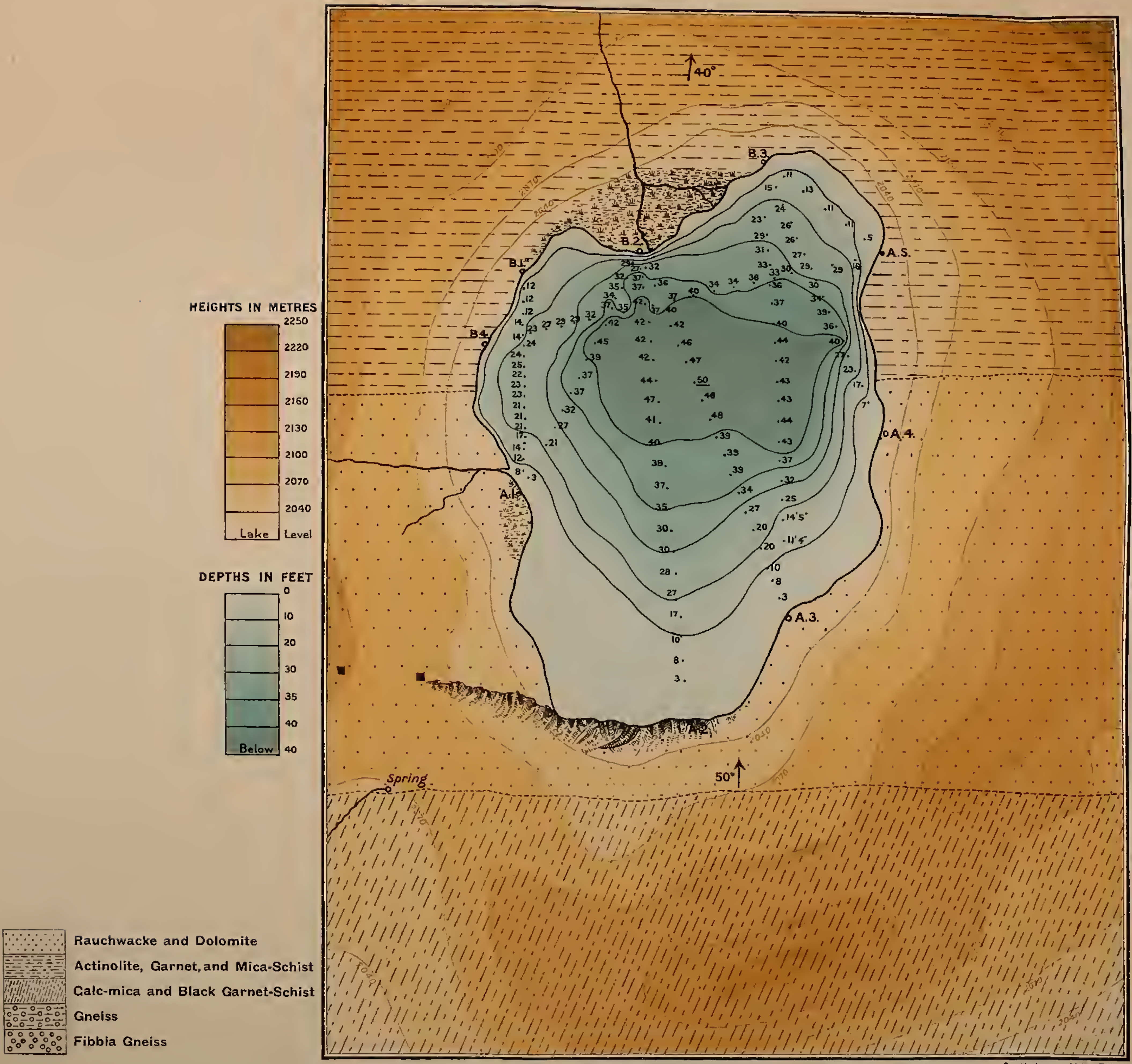
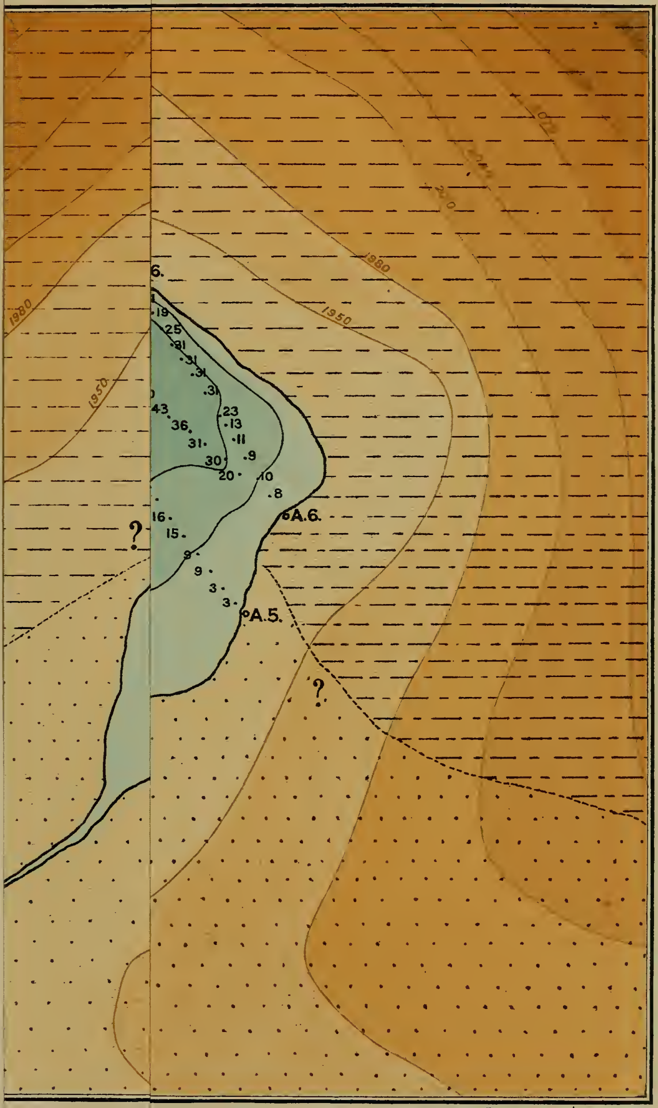


Bartholomew, Litho, Edinr

CONTOURED MAP OF LAGO TOM (2023 M.)

QUART. JOURN. GEOL. SOC. VOL. LXII, PL. XVIII.



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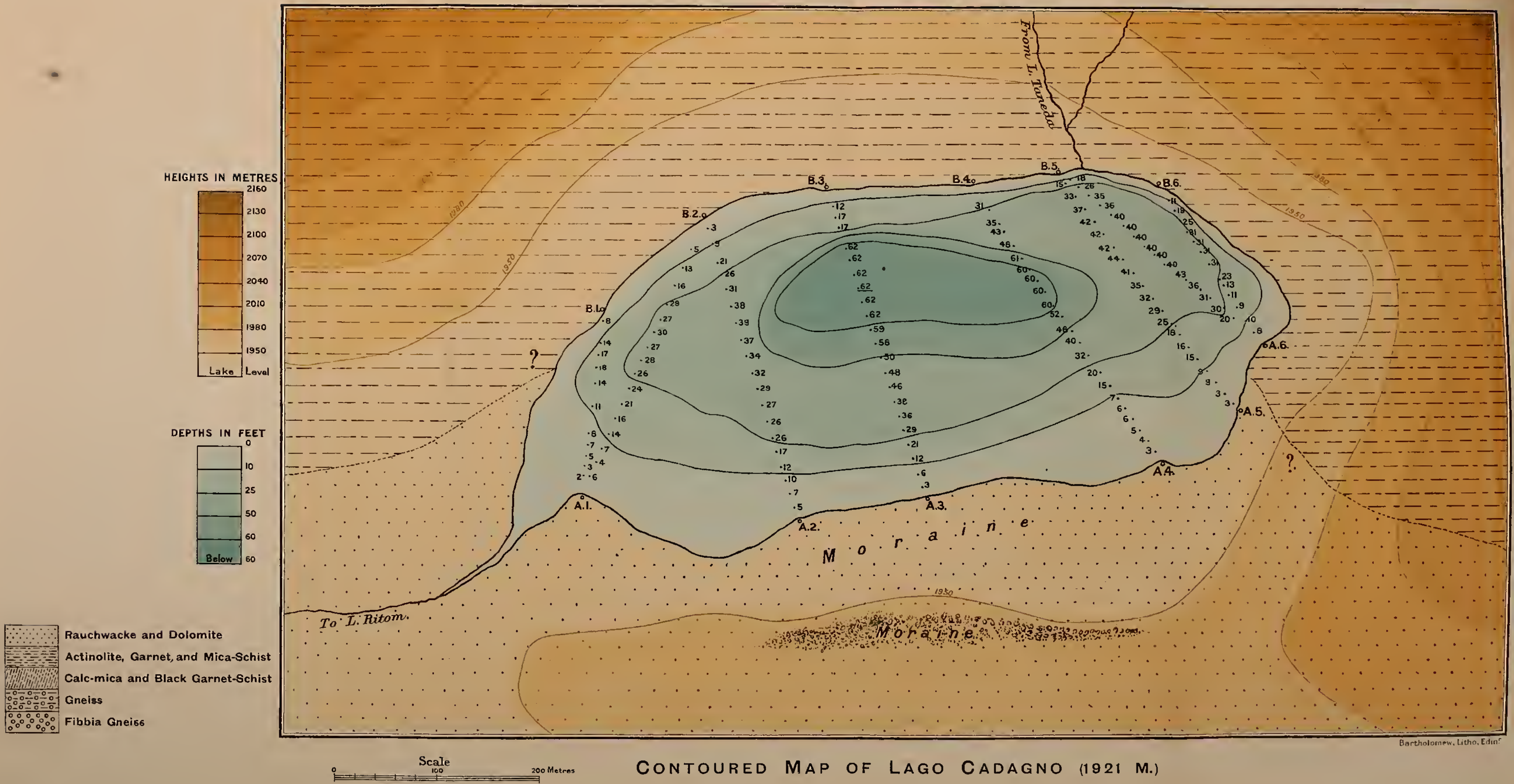
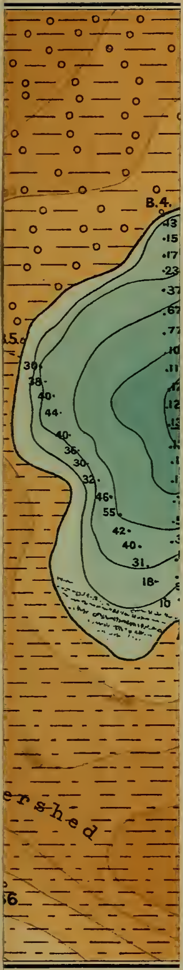


Bartholomew, Litho, Edin.r

CONTOURED MAP OF LAGO CADAGNO (1921 M.)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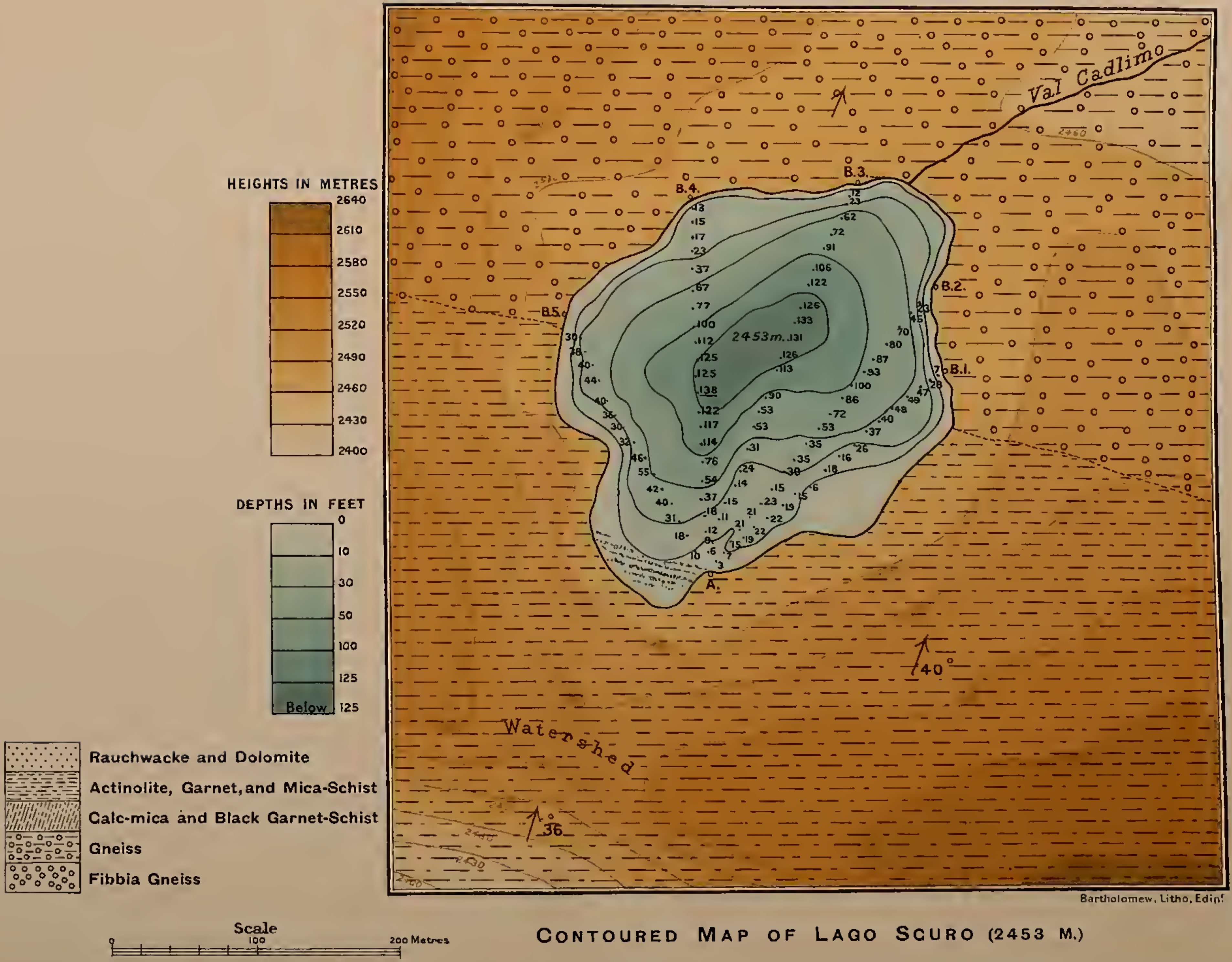
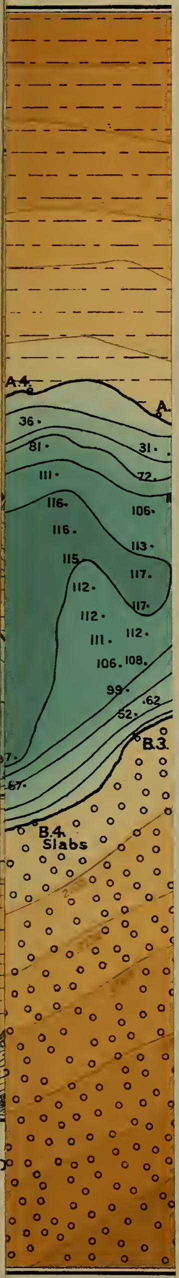


Bartholomew, Litho, Edin.

CONTOURED MAP OF LAGO SCURO (2453 M.)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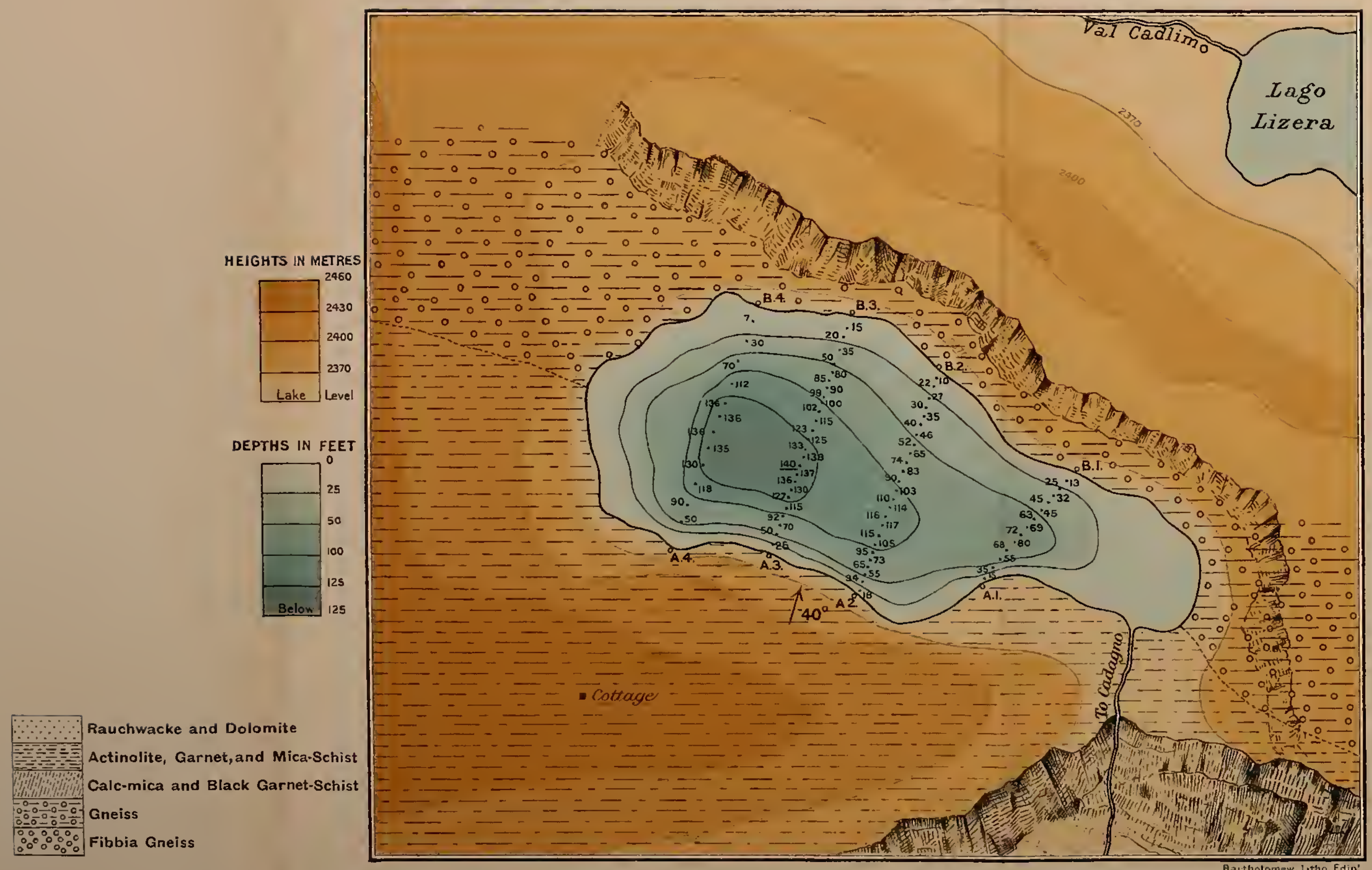
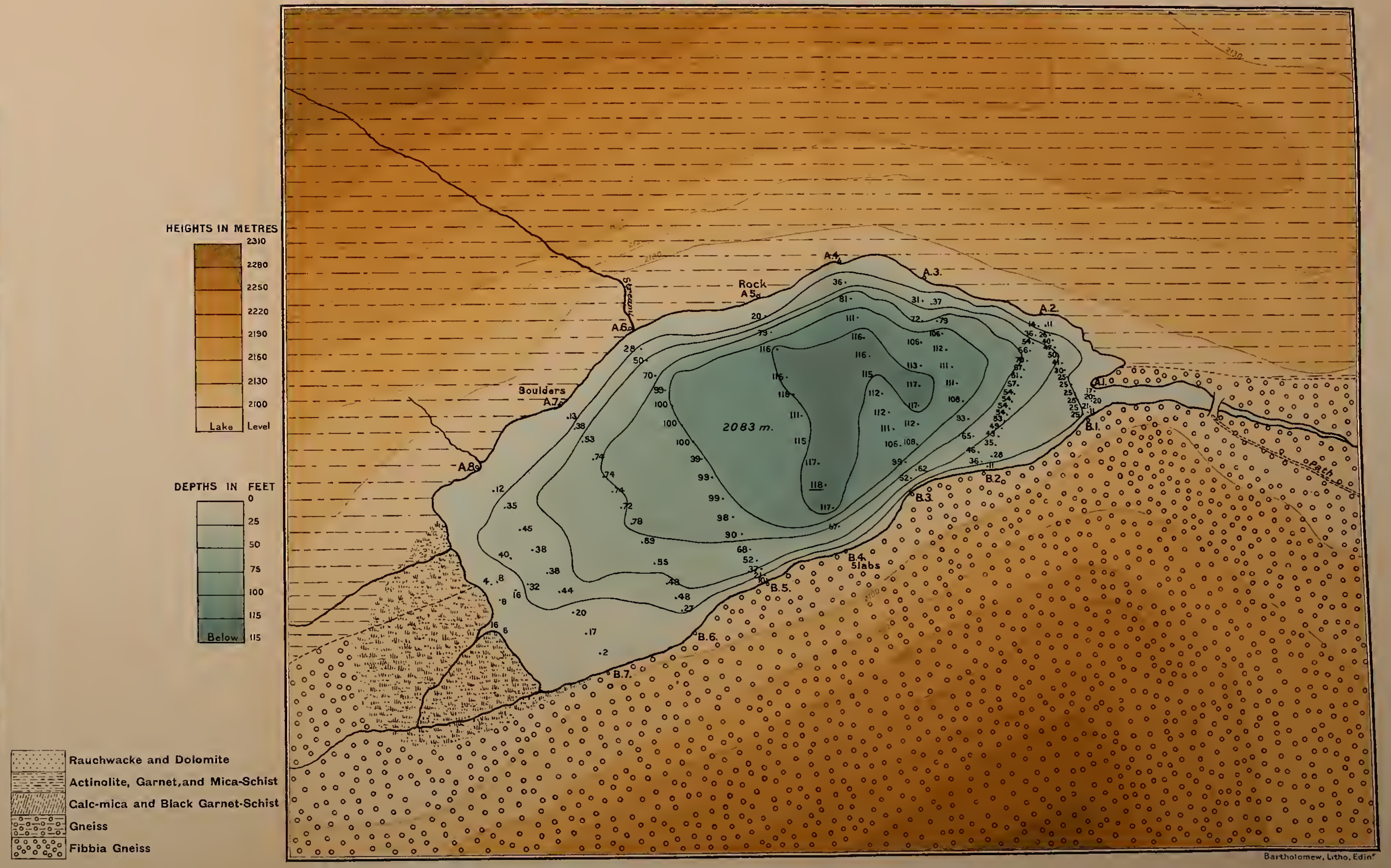


CONTOURED MAP OF LAGO TANEDA (2359 M.)



CONTOURED MAP OF LAGO LUCENDRO (2083 M.)

Plate XVIII.

Contoured map of Lago Cadagno, on the scale of 5000 : 1.

Plate XIX.

Contoured map of Lago Scuro, on the scale of 5000 : 1.

Plate XX.

Contoured map of Lago Taneda, on the scale of 5000 : 1. *For* 'Lizera' *read* 'Lisera.'

Plate XXI.

Contoured map of Lago di Lucendro, on the scale of 5000 : 1.

Discussion.

The President observed that he would have liked to say much which, on account of the lateness of the hour, he must omit. He thought that the case of the deep lakelet Scuro and its companion, situated close below the watershed, was a hard nut for advocates of glacial erosion of such lakes to crack. He could not sit down without referring to the amount of labour devoted by the Author, not only to the study of the lakes, but also to the preparation of his paper for presentation to the Society.

Prof. Bonney heartily concurred with the President's remarks on the thoroughness with which the Author had worked out his subject and the clearness of his exposition. He should like to state, for the information of the Fellows, that, in those lakes which he had described in the 'Geological Magazine,' he had not admitted that ice could have done more than form the rock-basin now filled with water. He had supposed, for instance, at the Lago di Tremorgio, that first a corrie was formed in the usual way by streams, and then, when the ice advanced, the descending mass might have a scooping effect, at the foot of so deep a slope. In regard to Lake Ritom, he felt doubts as to whether the headlands on the south side could be due to flexures, for these would correspond with the north-north-east to south-south-west folding, which he thought was on a large scale and was older than the east-to-west folding; he doubted also whether the nipped-up east-to-west strips of rauchwacke were sufficiently large to cause, when dissolved, so complete a removal of the intervening wedges of much less soluble rock. The idea of reversal in the Piora-Valley drainage presented difficulties to him. If the water escaped eastward (supposing the floor to be nearly at its present level), it would have to go over a pass now at least 1200 feet above the lake. He thought also that the deepening of the main valleys, to which the 'hanging valleys' were due, had been pre-Glacial, and that probably this part of the Val Bedretto would have been under ice, even in inter-Glacial times. But, while reserving judgment on these points until he had read the paper, he was none the less sensible of its value.

Dr. Johnston-Lavis asked the Author whether he had seen any signs of carbonic-acid springs in the sites of these curious lakes.

It struck him as curious that the soluble rocks should be dissolved only at some spots, and not at others where the active movement of streams would make one expect solution to be more rapid. Such irregularity pointed to some additional local agency, such as gas-laden springs, in determining the site of some of these lakes. Their occurrence also at the junction of different rocks would be partly explained by the crushing produced in earth-movement by differential shearing at such junctions. He quite agreed that glacier-action did not explain their origin. He would also remark that the minerals of the mica-group were much more soluble in a solution of carbon-dioxide than was usually supposed.

The AUTHOR thanked the President and Prof. Bonney for their kind remarks. In reply to the latter, he said that he thought the division on Dr. K. von Fritsch's map, between the rauchwacke and the calcareous schist at the western end of Lake Ritom, rather an artificial one, at all events so far as solubility was concerned; and there may have been no really-insoluble ridge, as he had traced massive calcareous rocks round that end of the lake as far as the gully shown in the photograph, while dolomite came in again still farther round at the lake-level. With this exception, he quite agreed with Prof. Bonney as to the difficulties in accounting for everything by solution. In regard to the excavation of Lago Tremorgio by ice, he had set out fully in the paper the difficulties that he found in accepting this explanation. He thought that the reversal of the Ritom drainage had begun at a much higher level. The lakes, however, did not depend on this.